PERIODICAL
V.10,no.2
DEC
SHED
Norway - Fisk.
FISH & WILDLIFE SERVICE
PACIFIC MARINE FISHERY
INVESTIGATIONS

FISKERIDIREKTORATETS SKRIFTER
Serie Havundersøkelser
(*Reports on Norwegian Fishery and Marine Investigations*)
Vol. X. No. 2.
Published by the Director of Fisheries

The Lusterfjord Herring

AND ITS ENVIRONMENT

BY
Olav Aasen

1952

A.s John Griegs Boktrykkeri, Bergen

FISKERIDIREKTORATETS SKRIFTER
Serie Havundersøkelser
(*Reports on Norwegian Fishery and Marine Investigations*)
Vol. X. No. 2.
Published by the Director of Fisheries

The Lusterfjord Herring

AND ITS ENVIRONMENT

BY
Olav Aasen

1952

A.s John Griegs Boktrykkeri, Bergen

CONTENTS

INTRODUCTION . . . . . Page 7
THE LUSTERFJORD . . . . . » 8
Bottom topography . . . . . » 8
Hydrography . . . . . » 10
Fauna . . . . . » 15
Plankton . . . . . » 15
Nekton . . . . . » 18
Benthos . . . . . » 19
THE LUSTERFJORD HERRING . . . . . » 22
Age . . . . . » 22
Vertebrae . . . . . » 24
Length . . . . . » 28
Weight . . . . . » 31
Growth . . . . . » 33
Maturity cycle . . . . . » 36
Intestinal fat . . . . . » 50
Condition factor . . . . . » 53
SUMMARY . . . . . » 58
LITERATURE . . . . . » 62
PLATES . . . . . » 64

Digitized by the Internet Archive
in 2025

https://archive.org/details/fiskeridirektoratets-skrifter-serie-havundersokelser_1952_10_2

PREFACE

The present paper is an account of a local herring »race« heretofore not described in the literature. The author is greatly indebted to Fiskeribedriftens Forskningsfond whose grants have made this work possible. Thanks are also due to Director Gunnar Rollefsen and Fishery-Consulent Finn Devold who have entrusted me with the planning and execution of these investigations. To Dr. Joachim Devold, Luster, who primarily has drawn our attention to the herring fisheries in the Lusterfjord, I wish to convey my most heartfelt gratitude. Special thanks are directed to Mr. Erik Havhellen who has carried out most of the field work, providing the majority of the herring and plankton samples and carrying out nearly all the hydrographical observations. To Dr. Jens Eggvin I express my sincere thanks for supplying the hydrographical apparatus and to his department for carrying out the titrations and preparing the hydrographical drawings. I also wish to thank Mr. Arne Revheim who participated in the cruise to the Lusterfjord when the investigations started and whose experience with echo-sounders was very valuable when the soundings for the depth-chart were made. My most cordial thanks are due to Mr. Kaare Gundersen who has worked up the plankton material, and to Mr. Ditlef Rustad who has kindly placed his observations on the Lusterfjord fauna at my disposal; also to the Geophysical Institute, Bergen, whose unpublished observations on the hydrography of this area have been lent to me through the courtesy of Professor Dr. Bjørn Helland-Hansen. Thanks are also due to Professor Dr. Hans Brattström and Professor Dr. C.-L. Godske for criticism of the paper. I am very grateful to Mr. Thorolv Rasmussen who has been reading the scales of the herring, and whose unique experience in scale readings will vouch for the correct interpretation. Further I am indebted to Mr. Leif Øyen Erichsen and Mr. Oddvar Dahl for various assistance during the work, and finally, I wish to express my gratitude and most cordial thanks to Dr. William Hodgson for reading over and amending the English text.

Bergen, December 1951.

Olav Aasen.

INTRODUCTION

In some of the Norwegian fjords there have been found to exist local herring »races« which differ more or less sharply from the main Norwegian herring stock, the Winter herring (or, as it will sometimes be called here, the Oceanic herring). The best known of these local herring »races« are the Lysefjord herring (O. S. Jensen 1881, Einar Lea[1], the Beitstadfjord herring (G. O. Sars 1891, Hjalmar Broch 1908), and the Borgepoll herring (Thorolv Rasmussen 1941).

Doubtless several more local herring tribes could be found in the numerous fjords along the Norwegian coast if the matter were thoroughly investigated. Last year (1949), for instance, one was found in the Lusterfjord, one of the innermost branches of the Sognefjord (Fig. 1). For this herring the name »Lusterfjord herring« is proposed, as the name used by the local fishermen, »Garnsild«, (meaning »Net herring«) is not

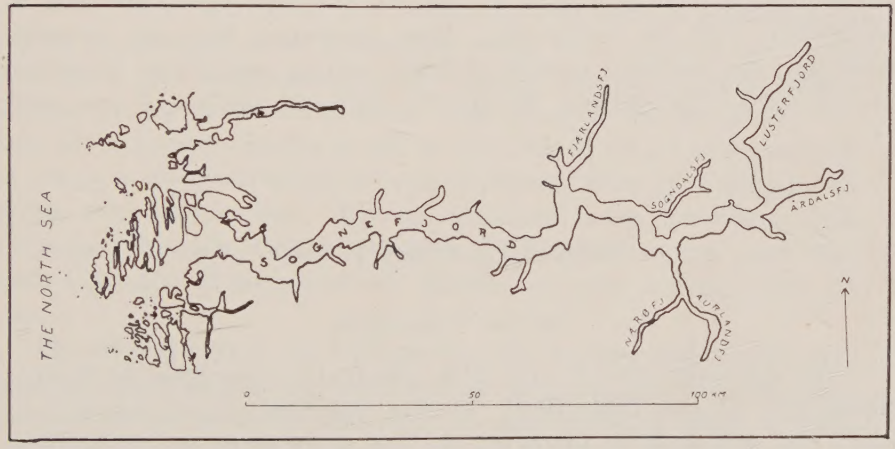


Fig. 1. The Sognefjord and its tributary fjords.

[1] Lea's results are partly published in Hjort's paper: »Vekslingerne i de store fiskerier« (Johan Hjort, 1914).

found suitable. The description of this particular herring »race« will be the chief object of this paper.

In some ways a local herring »race« in its fjord or basin can be regarded as a miniature model of the larger stocks of herring which live in the ocean, but such a local herring tribe with its very narrow living space may be comparatively easily followed all the year round and studied in relation to its environment which can easily be kept under continuous observation. It will be more or less like working in a giant aquarium, but of course, one cannot change the external factors at will, but on the other hand, one may be perfectly sure that the animals under observation have been thoroughly adapted to their environment.

Continuous observations over many years may be expected to throw light upon such obscure questions as fluctuations in the maturing cycles of adult herring with corresponding fluctuations in the time of the spawning influxes and the actual spawning; further, the process of the building up and breaking down of intestinal and muscle fat, the production of rich and poor year-classes, the plasticity of the vertebral number etc., can be studied.

When it was decided to tackle these problems by investigating a local herring »race«, the Lusterfjord herring was selected, the fjord being conveniently situated in the neighbourhood of our laboratory, and the fact that samples could be obtained all the year round made it even more convenient. The work has now been in progress for one year (Nov. 1949 — Dec. 1950), and although the results so far do not solve the more intricate problems on the programme, it has been possible to establish a »new herring race« hitherto unknown to science, and to accumulate data for future use. Also, interesting facts are recorded regarding the maturity process of adult herring and of the intestinal fat-content of the herring during the different seasons of the year.

THE LUSTERFJORD

Bottom Topography

The sea charts provide very little information regarding the bottom topography of the Lusterfjord. It was therefore found desirable to carry out soundings in the fjord, and on a cruise to the Lusterfjord in Nov. — Dec. 1949, echo-soundings were made for the construction of a depth-chart (Plate I). In Fig. 2 are drawn in the different courses along which the soundings were made. The degree of accuracy cannot

be expected to be of the same standard as the official surveys, nevertheless the depth-chart presented in Plate I, gives a fairly correct picture of the bottom relief in the fjord.

Following the deepest part of the fjord, it will be noted that at the entrance there is a slightly pronounced saddle with a depth between 550 and 600 metres. From there and inwards the bottom slopes down to between 650 and 700 metres, which depth is held for about 10 kilometres. When approaching Urnes, the flat part of the bottom narrows and rises rather steeply to a depth between 300 and 350 metres between Kriken and Raaum. Going further inwards the flat part of the bottom again broadens and the depth will be seen to exceed 350 metres as far as Næs. In the small tributary fjord going westwards from Næs, the bottom slopes evenly towards its end part, Marifjæren. From Næs to Dale the deepest part lies roundabout 300 metres. This part is somewhat narrow to start with, but past Nattroppenæs and Fagernæs it widens again and stays so until Dale where it narrows to a cleft and rises steeply up to a depth slightly exceeding 100 metres. This depth is held until Fjøsne and therefrom the bottom slopes evenly up towards the end of the Lusterfjord, Skjolden. In long section, the Lusterfjord may be compared to a giant staircase, the bottom rising some hundred metres at each step.

In cross section, the fjord is predominantly U-shaped in most parts, the sides being very steep. Exception are found at the sudden rises along the deepest part where the cross sections are V-shaped. In general, the eastern side is seen to be steeper than the western side.

It will be evident from this description that there is nothing in the bottom topography of the Lusterfjord which would confine the herring to the fjord, and the possibility exists that the herring at certain times of the year migrate outside the fjord. This question will be subject to a closer investigation. Futher it vill be seen that there are comparatively few places in the fjord which offer good opportunities for fishing for the herring with bottom nets, although successful trials have been made at Fjøsne, Skjolden, Ottum, Kjødnes, Fladhammerholmen, and Næs, where the water is comparatively shallow at some distance from the shore.

The deepest part of the bottom is mostly covered with muddy clay, the steep sides being mostly solid rock or large stones. In parts where the slope is not so steep, and even in some instances where it forms small plateaux, the bottom consists of mud or clay or both, although small stones also may be met with.

According to information furnished by the local fishermen, the Lusterfjord herring spawn almost on the same locality every year

(Ottum), but in varying depths. They are, however, not so particular about the bottom conditions as are the Oceanic herring, and this year (1950) herring spawn was found even on clay bottom.

Hydrography

Professor Helland-Hansen has investigated the hydrography of the Lusterfjord throughout a series of years from 1916 to 1937. The results are not published, but the author has been given the opportunity to go through the observations. Of course, these data are of little value in connection with the present investigations, as no herring samples were taken at that time, but they do show, however, that considerable changes might be expected to take place in the upper layers, this being a necessary condition for the success of the longer term investigations.

On the above-mentioned survey cruise to the Lusterfjord a series of hydrographical stations was taken from the entrance of the fjord towards the end part. The positions of the stations are shown in Fig. 2. Observations were taken in the standard depths down to 300 metres or to the bottom where the depth was less. The result is presented in Fig. 3 which shows isotherms and isohalines in a long-section of the Lusterfjord in late autumn 1949.

It will be seen that the hydrographical conditions are rather uniform

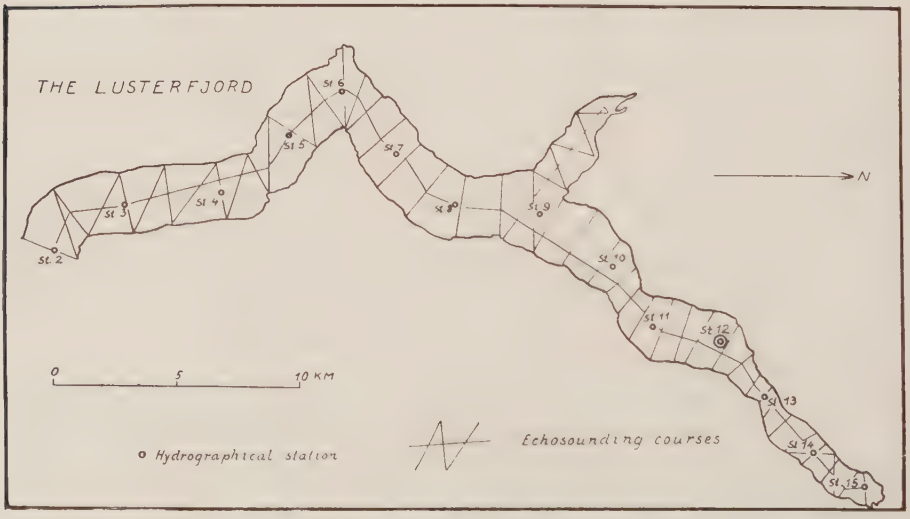


Fig. 2. The Lusterfjord. Positions of hydrographical stations. Courses along which the echo-soundings were made Nov.—Dec. 1949.

Fig. 3. Hydrographical long section of the Lusterfjord, Des. 1949.

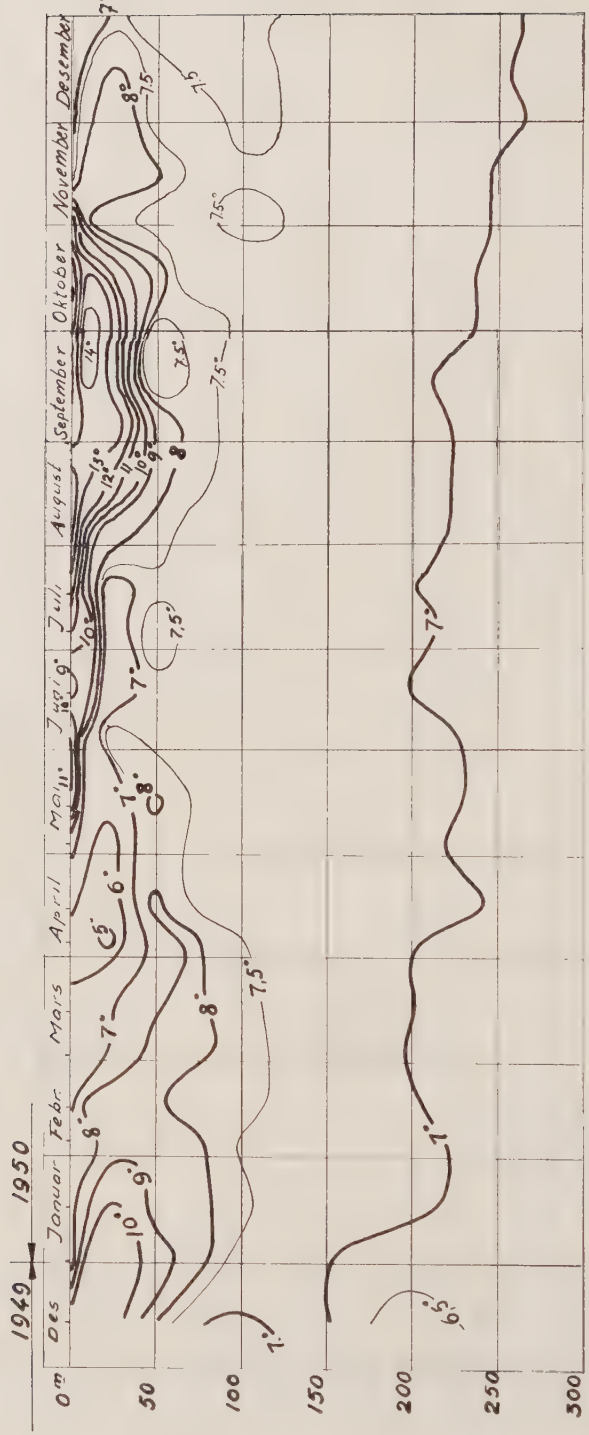


Fig. 4. Temperature variations in the Lusterfjord, December 1949 — December 1950.

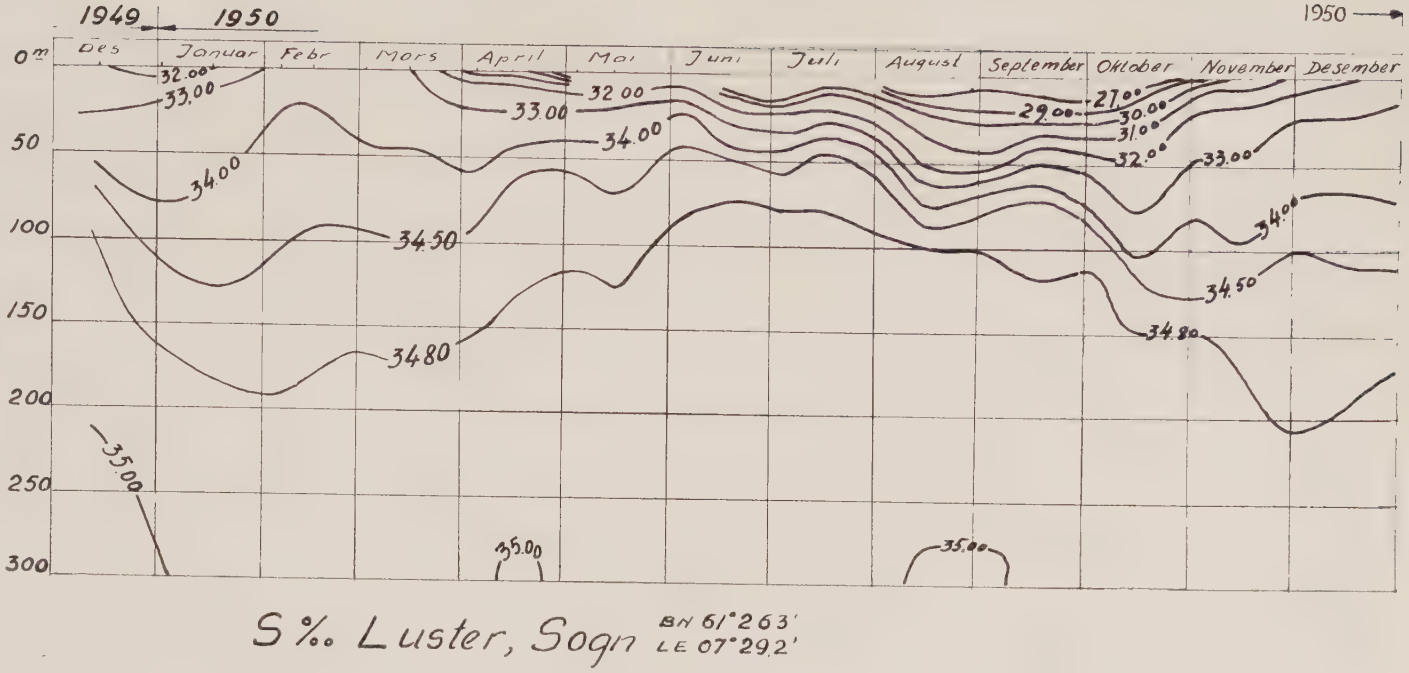


Fig. 5. Salinity variations in the Lusterfjord, December 1949 — December 1950.

Fig. 6. Oxygen variations in the Lusterfjord, February — December 1950.

throughout the fjord, which is an advantage because observations taken at one place may be expected to give information about the whole area. As a permanent observation point station 12 (Figs. 2 & 3) was chosen, and here, fortnightly temperature observations have been carried out in all the standard depths down to 300 metres during 1950. At the same time water samples for salinity and oxygen determinations have been collected in the same depths.

Apparently the hydrographical conditions in the Lusterfjord are very stable. The temperature variations in 300 metres, for instance, do not exceed 0.06 C ° throughout the whole fjord in December 1949 (Fig. 3). During the year 1949—1950 (Fig. 4) the temperarure at the same depth does not vary more than 0.15 C °, and during the whole interval 1916—1950 the difference between the highest and lowest temperature observed, is not more than 0.40 C °. This is due to the stratification of the water masses. The upper layers have a comparatively low salinity (Fig. 5) owing to the fresh water carried into the sea by rivers and numerous burns, especially during the spring and summer when large quantities of ice water come from the glaciers in the higher surrounding mountains. Consequently the upper layers have a great stability, and neither the summer heating nor the winter cooling are traceable down to any great depth.

Of particular interest are the hydrographical conditions during the spawning season. As will be seen later (Fig. 15 & Table 8) the spawning took place in March—May, mainly in April, at depths between 5 and 15 metres. The limits were found by placing long ropes at intervals on the bottom in the area before the spawning started, and then inspecting them regularly during the spawning period when samples of eggs were collected. The temperature at this time of the year in the water-layer in question is seen to lie between 5 and 7 C° (Fig. 4), the salinity being 31—33 $^{0}/_{00}$ S (Fig. 5) and the oxygen content approximately 8 cm³/litre (Fig. 6).

A more detailed description of the hydrography of the Lusterfjord is beyond the scope of this report.

Fauna

Plankton

Plankton samples have been collected fortnightly at the same place and at the same time as the hydrographical observations, but only zoo-plankton samples were taken. Vertical hauls were made from 300 metres to the surface and from 50 metres to 0 metre, using a 8 72 plankton net.

Of the collected material, only the hauls 50—0 metre have been properly worked up, the work having been done by Mr. Kaare Gundersen who has kindly furnished the data for the following survey of the zooplankton in the Lusterfjord from December 1949 to November 1950:

Species	December		Jan.	February		March		April	
	13th	31st	16th	4th	14th	1st	14th	3rd	13th
Pleurobrachia pileus	—	—	—	—	—	—	—	—	—
Tomopteris	—	—	—	—	1	—	—	—	—
Polychaet (larvae)	—	—	—	—	—	—	—	300	10
Podon	—	—	—	—	—	—	—	—	—
Evadne	—	—	—	—	-	—	—	50	5
Conchoecia	—	few	—	—	—	—	—	—	—
Cirriped (nauplius)	—	—	—	—	—	—	—	100	15
Cirriped (cypris)	—	—	—	—	—	50	—	—	—
Calanus finmarchicus	11	3	3	1	5	1	few	185	19
Paracalanus parvus	200	100	—	—	—	—	—	—	—
Pseudocalanus minutus	150	400	100	—	—	—	100	—	5
Microcalanus pusillus	1 600	600	500	—	10	—	200	300	—
Aetideus armatus	few	few	few	3	10	1	—	—	—
Chiridius armatus	—	—	—	—	—	—	—	—	—
Pareuchaeta norvegica	—	—	—	—	—	—	—	—	—
Scolecithricella minor	—	few	few	—	5	—	—	—	—
Centropages typicus	—	—	—	—	—	—	—	—	—
Temora longicornis	—	—	—	—	—	—	—	150	—
Metridia longa	—	—	—	2	—	—	—	—	—
Metridia lucens	10	few	2	—	5	—	50	50	5
Acartia clausi	—	200	—	1	—	—	50	1 250	80
Oithona helgolandica	1400	2 600	—	—	20	few	1 200	1 300	25
Oithona spinirostris	—	—	—	2	15	few	—	100	—
Oncaea borealis	600	300	550	—	5	—	300	1 000	-
Harpacticoids	200	—	100	—	10	—	50	—	—
Thysanoessa	—	—	-	—	—	—	—	650	70
Pandalus (larvae)	—	—	—	—	—	—	—	1	—
Limacina	—	-	—	-	—	—	—	—	—
Cyphonautes	200	600	150	—		—	-	—	5
Echinoderm (larvae)		—	—	—	—	—	—	—	—
Sagitta	—	—	—	—	—	—	—	—	
Krohnia	8	7	6	2	7	—	—	1	—
Fritillaria borealis	200	-	—	—	—	—	—	50	—
Oikopleura	—	—	50	—	-	—	—	—	—
Herring (larvae)	—	—	—	—	—	—	—	—	—
Sprat »	—	—	—	—	-	—	—	—	—
Gadidae »	—	—	—	—	—	—	—	—	—
Macruridae (egg)	—	—	—	—	—	—	—	—	—
Fish eggs (unspecified)	—	—	—	—	—	—	—	5	

In Fig. 7 are shown the variations in the volume of plankton per haul from January to November 1950. The upper graph (unbroken line) represents 300—0 m, corresponding to ca. 120 m^3 of sea water. Lower graph (broken line) represents 50—0 m, corresponding to ca.

May		June		July		August		September		October		November	
2nd	13th	2nd	15th	3rd	14th	1st	14th	1st	15th	2nd	14th	1st	14th
—	—	—	—	—	—	11	33	50	6	2	5	3	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	10	—	—
—	100	600	100	—	100	—	—	100	25	100	25	—	—
50	100	1 300	100	50	200	—	—	—	—	10	—	—	—
—	—	—	100	—	—	—	—	—	—	—	—	5	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
600	200	200	700	250	450	3	100	4	3	16	5	5	20
—	—	—	—	—	—	—	—	—	—	—	5	30	50
550	450	2 500	850	800	300	50	150	200	5	—	25	10	10
—	—	400	—	—	—	—	300	—	—	30	—	5	130
—	—	—	—	—	50	—	—	—	—	—	—	—	—
—	—	1	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	2	5
—	few	—	—	—	50	—	—	—	—	—	—	5	5
—	—	—	few	—	—	—	—	—	—	—	—	—	—
700	50	12 400	1450	1 150	250	100	400	100	10	20	—	—	—
—	—	100	—	—	few	—	—	—	—	—	—	6	20
few	few	50	few	few	—	—	few	few	few	3	20	—	—
1 000	250	7 000	1 650	1 150	260	50	250	—	5	10	—	—	10
650	100	9 000	2 100	900	1 600	150	1 000	150	75	110	110	65	110
—	—	400	—	—	—	50	—	—	—	—	—	—	—
250	350	4 200	1 100	800	900	—	200	50	40	10	—	—	20
—	—	200	—	—	200	150	—	—	5	30	55	60	50
50	50	1	1	2	5	40	—	—	1	—	3	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	200	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	100	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	1	—	—	—	—	—	—	—	6	4
—	—	—	—	—	—	—	—	—	—	—	5	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	1	—	—	—	—	—	—	—	—
—	—	1	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	1	—	—	—	—	—	—	—
5	—	14	6	4	5	—	20	—	—	—	—	—	—

2 — Olav Aasen.

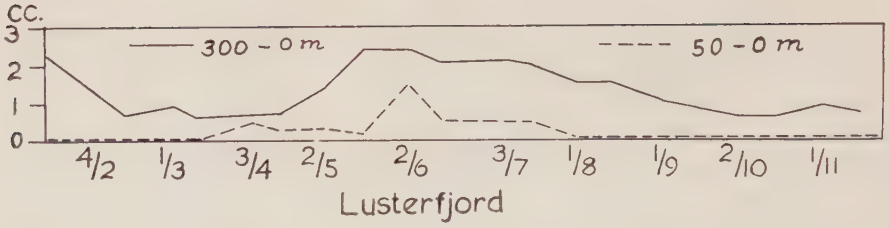


Fig. 7. The variations in the volume of plankton (cm^3) per haul, January — November 1950. 300 — 0 m upper graph, 50 — 0 m lower graph. (After Gundersen).

20 m^3 water. The volume is expressed as cm^3 per sample, found by measuring the volume of sample + water (a) and the volume of the water after filtration and gentle squeezing of the residue (b), the difference (a-b) being the volume of the plankton (Gundersen 1950).

It appears that the zoo-plankton production in the Lusterfjord is very poor. This feature may possibly in some way account for the small size of the Lusterfjord herring (see later). The amount of plankton in the upper 50 m is quite negligible outside the months April—July. Also in the deeper layers (300—50 m), — the difference between the two graphs — the volume of plankton is small considering the large water column (120 m^3) filtered for plankton (Gundersen 1951).

Nekton

From different sources, of which may be mentioned Mr. Ditlef Rustad's (unpublished) data on fishes in the Lusterfjord, the following list of the nektonic animals in the fjord has been compiled. This list is scarcely complete, but it may, however, be said to comprise the more common species.[1]

CEPHALOPODA
Rossia macrosoma

CYCLOSTOMATA
Myxine glutinosa

PISCES
Chimaera monstrosa
Pristiurus catulus
Squalus acanthias
Spinax niger
Raja fullonica
Clupea harengus
» sprattus
Salmo salar
» trutta
Argentina silus
» sphyraena
Anguilla vulgaris
Myctophum glaciale
Gasterosteus aculeatus
Gadus morrhua

[1] Some of these are not nektonic, strictly speaking, as for instance the flatfishes which are able to leave the bottom and traverse the water at will for shorter intervals only.

PISCES (cont.)
Gadus virens
» pollachius
» aeglefinus
» poutassou
» minutus
» merlangus
Gadiculus argenteus
Molva dipterygia
Merlucius merlucius
Onos maculatus
Hippoglossus hippoglossus
Hippoglossoides platessoides
Pleuronectes flesus
» platessa
» cynoglossus
Lepidorhombus whiff
Scophthalmus norvegicus
Rhombus laevis
Caranx trachurus
Scomber scombrus
Thunnus thynnus
Gobius niger
» minutus
Cottus bubalis
Artediellus uncinatus
Trigla gurnardus
Centronotus gunellus
Zoarches viviparus
Lycodes sarsi
Ramphistoma belone

Some of these species are known to be predators on the herring, as for instance, some of the *Gadus sp.* which have been found with herrings in their stomachs. The sharks doubtless also prey heavily on the herring. Frequently the net-caught herrings are damaged through shark bites and several times specimens of *Spinax niger* and *Squalus acanthias* have been caught entangled in the herring nets when eating the captured herring from the nets. *Squalus acanthias* especially, appear to be very numerous at times in the Lusterfjord, and once, over one hundred specimens were caught in one hour's haul with prawn trawl. The majority of these were small, about 28 cm, and apparently newly born. In one of the adult females (105 cm), 23 living young were found (December). *Thunnus thynnus*, which visits the fjord during late summer and autumn, is also a notorius herring eater. On the other hand, herrings have been found with small fishes of different species in their stomachs, and also, for that matter, their own young.

Benthos

The bottom fauna of the Lusterfjord has been investigated by Mr. Ditlef Rustad during a series of years. The material has not yet been worked up and no data have been published. Mr. Rustad has, however, kindly given me the opportunity to go through his notes made during the field work. These notes deal mostly with the larger and more familiar species thrown away when sorting the material, and the following survey which is based on these recordings is, consequently, by no means complete. It is pointed out that no attention has been paid to the depths at which these animals are found.

Bentic animals in the Lusterfjord.

(Compiled after Rustad's observations)

SPONGIARIA

Geodia sp.
Phakellia sp.

HYDROZOA

Unspecified

ANTHOZOA

Kophobelemnon stelliferum
Funiculina quadrangularis
Virgularia sp.
Gonactinia prolifera
Bolocera tuediae
Actinostola callosa

NEMERTINI

Unspecified

ANNELIDA

Nereis sp.
Eumenia crassa
Ammotrypane sp.
Pectinaria sp.
Serpula vermicularis
Pomatoceros triqueter
Placostegus tridentatus
Ditrupa arietina

»GEPHYREA«

Sipunculus norvegicus
Phascolion strombi
Bonellia viridis

CRUSTACEA

Ostracoda
Balanus sp.
Verruca stroemi
Cumacea
Haploops tubicola
Gammarus sp.
Idothea baltica
Lophogaster typicus
Crangon allmani
» vulgaris
Pontophilus echinolatus
» norvegicus
Spirontocaris sp.
Pandalus borealis

CRUSTACEA (cont.)

Pandalus propinquus
» bonnieri (?)
Calocaris macandreae
Lithodes maja
Eupagurus pubescens
Munida tenuimana
Inachus dorsettensis
Carcinus maenas

ACULIFERA

Unspecified

GASTROPODA

Patella sp.
Acmaea sp.
Gibbula cineraria
Littorina littorea
» saxatilis
Aporrhais pes-pelecani
Lunatia nitida
Buccinum undatum
Nassa reticulata
Acera bullata
Scaphander sp.

SCAPHOPODA

Dentalium entale

LAMELLIBRANCHIATA

Arca sp.
Anomia sp.
Pecten septemradiatus
» abyssorum
Lima hians
» excavata
Modiola modiolus
Mytilus edulis
Nicania banksi
Astarte sulcata
» compressa
Thyasira flexuosa (?)
Lucina borealis
Cardium echinatum
Cyprina islandica
Isocardia cor
Syndosmya sp.
Venus gallina

LAMELLIBRANCHIATA (cont.)
Saxicava arctica
Mya arenaria
Corbula gibba
Cuspidaria obesa
» rostrata

BRYOZOA
Hornera lichenoides
Retepora beaniana

BRACHIOPODA
Crania anomala
Waldheimia sp.
Terebratulina sp.

ASTEROIDEA
Astropecten irregularis
Ctenodiscus crispatus
Psilaster andromeda
Ceramaster granularis
Pseudarchaster parelii
Hippasteria phrygiana
Poraniomorpha hispida
Henricia sanguinolenta
Stichastrella rosea
Asterias rubens
» glacialis
Brisingella coronata (?)

OPHIUROIDEA
Ophiopholis aculeata

OPHIUROIDEA (cont.)
Amphilepis norvegica
Amphiura chiajei
» filiformis
Ophiura carnea
» sarsi
» texturata
» albida
» affinis
Asteronyx loveni

ECHINOIDEA
Echinus esculentus
» acutus
Strongylocentrotus droebachiensis
Brisaster fragilis
Echinocardium cordatum
» flavescens
Echinocyamus pusillus

HOLOTHURIOIDEA
Mesothuria intestinalis
Bathyplotes natans
Stichopus tremulus
Cucumaria elongata
» hyndmani
Thyone fusus
» raphanus
Psolus squamatus

ASCIDIACEA
Ciona intestinalis

Few, if any, of these animals are likely to be of any importance to the herring in their adult condition, although prawns have sometimes been found in herring stomachs[1]. However, when the young of most of the bottom-living animals form a part of the plankton, some of them will probably constitute a part of the herring's diet although necessarily to a small extent, at least as fas as 1950 is concerned, as will be evident from the plankton survey (page 16).

[1] It may be mentioned that during tagging work in the Winter herring district, *Idothea neglecta* has been found on the herring together with scores of *Caligus curtus*, also *Aega sp.* and *Rocinela sp.* were sometimes observed to prey on herring on the same occasions. The herrings lived, however, at the time not quite under natural conditions, confined as they were in land seines.

THE LUSTERFJORD HERRING

When sampling the Lusterfjord herring it has, unfortunately, not been possible to secure samples of the usual number (200 ind.) except during the spawning season. The herrings have been examined as to length, weight, sex, maturity stage, weight of gonads, Vert. S., age, intestinal fat, and growth. In some cases stomachs have been collected for examination, but this material has not yet been worked up. For practical reasons the observational data are not included in this paper, but may be obtained on request from the library of *Director of Fisheries, Institute of marine Research, Bergen.*

As only nets with meshes suited for catching the adult herring have been used in the Lusterfjord, the younger stages of the herring have only occasionally been met with. Sometimes »strange« herring may be found. Some of these can be recognized as Oceanic (Norwegian) herrings. In other cases the »strange« herrings do not conform either to the Oceanic type or to the Lusterfjord type (see Plate II). There are indications that these »strangers« normally inhabit other branches of the inner Sognefjord, but more material is needed to verify this. In the subsequent treatment, all the young herrings of the Lusterfjord type have been left out, and the same applies to the »strange herrings«, except where specially mentioned.

Age

As the majority of the samples are small, it is inconvenient to treat them separately. The procedure has therefore been adopted of grouping together all herrings caught within the same calendar months as one sample. Even then the number in some cases is regrettably low. The percentage age-frequency distribution for each month during the year November 1949 — November 1950 is presented in Table 1. Taken as a whole the age varies between 2+ and 10+ years. As usual in age distributions the percentages of the youngest and oldest age groups are low. Compared with the Oceanic herring the Lusterfjord herring is short-lived (Fig. 8), the adult population of the former having an age range of 3—20 years in 1950. The 1945 year-class appears to be predominant. Throughout the year, this year-class occurs more frequently in the samples than the other year-classes with exception of November 1950 when the 1946 year-class is the dominating group. Further it will be seen that the percentage of the 1945 year-class is appreciably higher towards the end of 1950 than that of the 1944 year-class was towards the end

of 1949. Similarly, the year-class 1945 was stronger in the latter part of 1949 than was the 1946 year-class in the autumn of 1950. From this

Table 1. Age frequency distributions of the Lusterfjord herring in the different months of the year Nov. 1949 — Nov. 1950 expressed as per cent of examined numbers.

Year-class / Age	1948 / 2	1947 / 3	1946 / 4	1945 / 5	1944 / 6	1943 / 7	1942 / 8	1941 / 9	1940 / 10	Number
Nov.-49	—	—	9.2	48.7	7.9	23.7	10.5	—	—	76
Dec. »	—	—	—	64.7	17.5	11.8	5.9	—	—	17
Jan.-50	—	—	4.4	64.4	13.3	13.3	—	2.2	2.2	45
Feb. »	—	—	28.6	57.1	—	14.3	—	—	—	7
Mar. »	—	0.4	10.8	61.4	12.4	11.6	2.7	0.8	—	259
Apr. »	—	0.3	8,1	50.1	13.5	17.8	8.6	1.1	0.5	371
May »	—	—	—	50.0	—	20.0	30.0	—	—	10
Jun. »	—	—	15.4	36.5	21.2	15.4	11.5	—	—	52
Jul. »	—	20.4	24.1	37.0	13.0	3.7	1.9	—	—	54
Aug. »	3.1	7.7	12.3	44.6	12.3	18.5	—	1.5	—	65
Sep. »	—	6.7	13.3	40.0	20.0	20.0	—	—	—	30
Oct. »	3.7	5.6	24.1	37.0	11.1	14.8	3.7	—	—	54
Nov. »	—	1.5	32.8	23.9	22.4	16.4	—	1.5	1.5	67
Total	0.4	2.2	12.4	49.5	13.6	15.5	5.4	0.8	0.4	1 107

follows that the 1945 year-class is relatively stronger than the 1944 and 1946 year-classes. The 1943 year-class also appears to be strong;

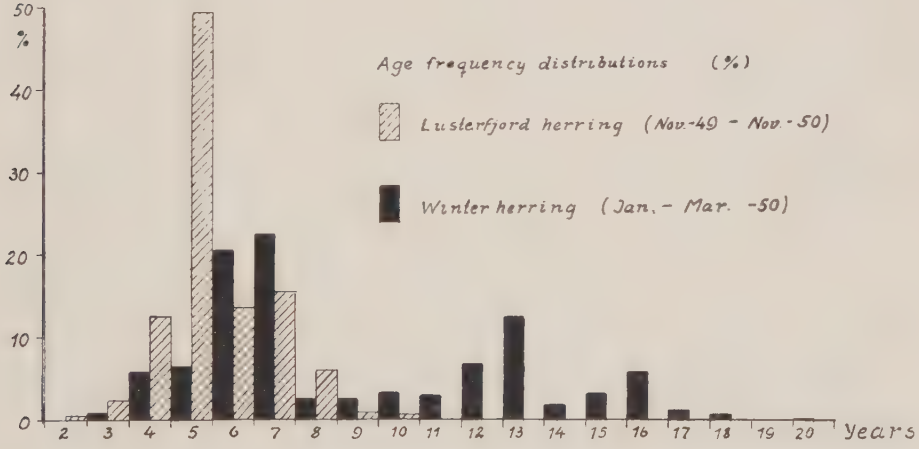


Fig. 8. The age frequency distribution of the Lusterfjord herring Nov. 1949 — Nov. 1950 (hatched columns) compared to that of the Winter herring Jan. — Mar. 1950 (black columns).

but whether or not it equals the 1945 year-class at the same age, cannot be solved at the moment as one has not sufficient material to estimate the mortality rate of the Lusterfjord herring. The same goes, of course, for the other year-classes.

Following the percentages for the 1945 year-class through the different months, a slow decrease will be noticed during the year. This means that this year-class had reached, if not passed, its maximum strength by the end of 1949. Similarly it will be seen that the 1946 year-class increases during 1950; but the material is scarce and the tendency is not so clearly shown. It is, however, reasonable to suppose that the year-classes reach their maximum strength at an age of 4—5 years.

Table 1 indicates further that the recruitment to the adult stock of herring takes place during summer and autumn, the oldest age-groups becoming relatively scarce at the same time.

Of particular interest for the continued investigations is the establishment of the fact that the different year-broods show a varying strength. This is a necessary condition to be fulfilled if the influence of the environmental factors on the production of year-broods is to be studied.

Vertebrae

As earlier mentioned the scale characters have been used to identify the Lusterfjord type of herring in the samples. The percentage of »strange« herring is small, amounting to 6—7 % in all. But even when these have been omitted, the question still remains to be solved whether or not the samples are homogeneous, that is if they can be said to be random samples from the same population. Obviously this is an important question, as it is necessary that the same population should be dealt with all the time. One of the most common characters used in distinguishing between different herring »races«, is the vertebral number. It is then reasonable to suppose that if the herring caught at different times of the year show no significant differences in vertebral number, one may be fairly sure that the samples are drawn from the same population. To test this, the Analysis of Variance (Fisher 1948) has been applied. Following the procedure from the preceding Section, all the herring caught within the same calendar month have been grouped together and treated as one sample.

In Table 2 is given the frequency distribution for Vert. S. in the different months from November 1949 to November 1950, leaving out March, as it is suspected that there may be some fault with the countings. In Table 2 are also entered:

n = number in sample

$S(x)$ = sum of (deviation · frequency)

$\bar{x} = \frac{S(x)}{n}$ = average excess above the »working mean« here chosen at 56 vertebrae.

$S(x^2)$ = sum of (deviation^2 · frequency)

σ^2 = variance $= \frac{1}{n-1} S(x-\bar{x})^2 = \frac{S(x^2) - \bar{x}S(x)}{n-1}$

σ = standard deviation

Table 2. Vertebrae frequency distributions of the Lusterfjord herring in the different months of the year Nov. 1949 — Nov. 1950. For further explanations see text.

Month	Vertebral Nos.						n	$S(x)$	$\bar{x}$	$S(x^2)$	σ^2	σ
	54	55	56	57	58	59						
Nov.-49	4	10	44	24	7	2	91	26	0.2857	96	0.9841	0.9920
Dec. »	—	2	10	5	3	—	20	9	0.4500	19	0.7868	0.8870
Jan. -50	1	14	23	11	3	—	52	1	0.0192	41	0.8035	0.8965
Feb. »	—	1	4	1	1	—	7	2	0.2857	6	0.9048	0.9512
Apr. »	2	58	219	148	10	1	438	109	0.2489	263	0.5397	0.7346
May »	—	1	7	3	1	—	12	4	0.3333	8	0.6061	0.7785
Jun. »	2	16	40	21	3	1	83	10	0.1205	66	0.7902	0.8889
Jul. »	1	8	32	21	3	—	65	17	0.2615	45	0.6337	0.7961
Aug. »	—	10	41	28	1	—	80	20	0.2500	42	0.4694	0.6851
Sep. »	—	4	15	15	3	—	37	17	0.4595	31	0.6775	0.8231
Oct. »	—	5	34	22	3	—	64	23	0.3594	39	0.4878	0.6984
Nov. »	—	14	40	23	6	—	83	21	0.2530	61	0.6791	0.8241
Total »	10	143	509	322	44	4	1 032	259	0.2510	717	0.6323	0.7952

Further calculations from the figures in Table 2 give a variance within samples: 0.6318 and a variance between means of samples: 0.6877. The variance ratio (e^{2Z}) is then:

$$F = \frac{0.6877}{0.6318} = 1.0885$$

This figure is not significant, (Fisher and Yates 1949), and the samples are accordingly homogeneous.

One may then regard the total Vert. S. distribution as one large sample and from this can be extracted the following information: The vertebral number of the Lusterfjord herring varies between 54 and 59 vertebrae, the variance being 0. 6323 and the standard deviation 0.7952.

The sampling variance of variance $\left(\frac{2\sigma^4}{n-1}\right)$ is 0.007756 or the standard error ($\pm$ twice the standard deviation) $\pm$ 0.0557. The variance of the vertebrae distribution is accordingly lying between the limits 0.5766 and 0.6880. The mean value of the vertebral number is 56.2510 with a sampling variance $\left(\frac{\sigma^2}{n}\right) = 0.0006127$ or a standard error $\pm$ 0.0495. From these figures it is seen that the mean of any (large) random sample from the population, shows significant aberration if it lies outside the limits 56.3005 and 56.2015.

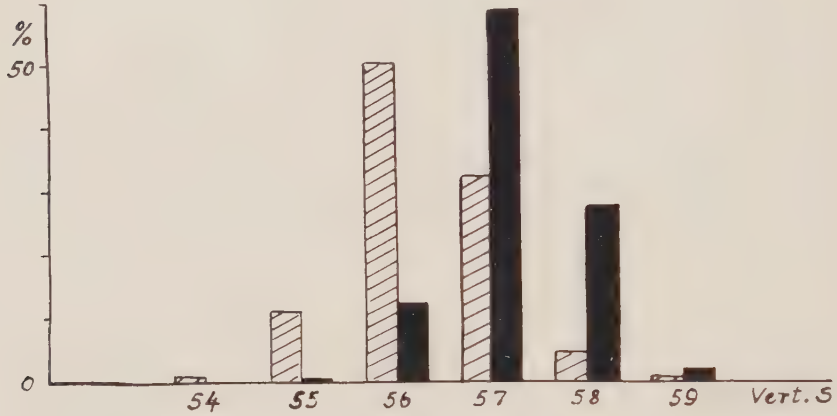


Fig. 9. The vertebrae frequency distribution of the Lusterfjord herring Nov. 1949 — Nov. 1950 (hatched columns) compared to that of the Winter herring Jan. — Mar. 1950 (black columns).

The mean vertebral number of the Norwegian Winter herring in 1950 differs notably from these values being 57.1761 (comprising 4412 specimens). There is no need to test the significance of this difference. In Fig. 9 is presented in graphical form the percentage frequency distributions in vertebral number of the Lusterfjord herring (hatched columns) and the Winter herring (black columns). The distributions in actual numbers are entered in Table 3. As will be seen, the distributions as well as the mean values, are entirely different.

It may be of some interest to take a closer look at the »strange« herrings found amongst the Lusterfjord herring. The frequency distributions in Vert. S. of these »strangers« are given in Table 3 and the statistics $\bar{x}$, $S(x)$, and $S(x^2)$ are also entered. As already stated, the means of the Vert. S. of the Lusterfjord herring and the Norwegian Winter herrring are significantly different. For testing the significance

Table 3. Vertebrae frequency distributions of Winter herring, Lusterfjord herring, »Strange« herring A, and »Strange« herring B. For further explanations see text.

Categories	Vertebral number							n	$S(x)$	$\bar{x}$	$S(x^2)$
	53	54	55	56	57	58	59				
Winter herring	2	2	13	517	2603	1216	59	4412	5189	1.1761	8037
Lusterfjord herring	—	10	143	509	322	44	4	1032	259	0.2510	717
»Strange« herring A	—	—	1	—	3	7	—	11	16	1.4545	32
»Strange« herring B	—	—	3	26	25	6	1	61	37	0.6066	61

of either two of the other means it is most convenient to use the t-test (Fisher 1948):

$$t = \frac{x - \bar{x}}{s} \sqrt{\frac{n_1 \cdot n_2}{n_1 + n_2}} \qquad \text{where}$$

$$s^2 = \frac{1}{n_1 + n_2 - 2}\left[S(x - \bar{x})^2 + S(x' - \bar{x}')^2\right]$$

When applying these formulae on the two types of »strange« herring, a t of 3.147 is found i.e. there is less than 1 % probalibity that this value would occur by chance. One may therefore conclude that these two types of herring belong to different tribes. The type »A« are those recognized as Oceanic herrings by the scale characters (page 22). Calculating t for this type and for the Winter herring, a value of 1.396 is found. This corresponds to a probalibity of 0.15, i.e. about 15 values in a hundred will exceed 1.396 by chance, so that the difference between the means is not significant. This corroborates the evidence furnished by the scale readings. In the same way is is found, as was to be expected, that the difference between the means of the type »A« herring and the Lusterfjord herring is highly significant, t being 4.9841 ($P < 0.01$). The »strange« herring of type »B«, which cannot be referred to either the Lusterfjord herring or the Winter herring by the scale characters, also show clearly significant differences in Vert. S. from either type, the t's being respectively 3.3026 and 6.6510 ($P < 0.01$.) The usual whereabouts of this herring is not known; but as already mentioned, there are indications that this »race« inhabits other branches of the inner Sognefjord. Some specimens from the Aurlandsfjord (Fig. 1) correspond to the type which, according to information furnished

by the local fishermen, is frequently caught there. If this really is the case, it would appear that these waters might furnish excellent possibilities for studying the factors governing »race« characters.

One of the items on the long term programme is to investigate the plasticity (or constancy) of the vertebral number. A necessary condition for this investigation is that the different year-broods show significant differences in their mean Vert. S. In Table 4 is presented

Table 4. Vertebrae frequency distributions of the different year classes (1942—1947) of the Lusterfjord herring. For further explanations see text.

Year class	Vert. S.						n	$S(x)$	$\bar{x}$	$S(x^2)$	σ^2
	54	55	56	57	58	59					
1942	—	9	26	15	1	—	51	8	0.1569	28	0.5349
1943	1	18	68	46	7	1	141	43	0.3121	105	0.6541
1944	2	15	57	39	5	—	118	30	0.2542	82	0.6357
1945	4	53	186	126	16	2	387	103	0.2661	277	0.6466
1946	—	18	58	27	4	—	107	17	0.1589	61	0.5500
1947	1	2	8	7	1	—	19	5	0.2632	17	0.8715
Total	8	115	403	260	34	3	823	206	0.2503	570	0.6307

the frequency distribution in vertebral number for the different year-classes 1942—1947, the older and younger year-classes have been left out as they comprise too few specimens. The March-samples are cut out as before. In Table 4 are also entered the statistics: x, $S(x^2)$, $S(x)$, and σ^2. From these data is calculated the variance between means of samples (year-classes) = 0.4331 and the variance within samples = 0.6319. This gives a variance ratio (e^{2Z}):

$$F = \frac{0.6319}{0.4331} = 1.46$$

This value is not significant and one will have to await circumstances that will produce year-classes with extraordinary values in vertebral number. Whether or not this will occur within a reasonable time cannot be known, of course, but the prospects do not seem too bright as 6 years in succession show no significant differences in vertebral number.

Length

When carrying out the sampling of the Lusterfjord herring, the length has been measured in most cases to the nearest millimetre, and

in some cases to the nearest 1/2 cm, the inconsistency in measurements being due to the fact that the sampling has been carried out by different persons in the author's absence, and that when starting the work, the usual procedure of group measurements was adopted. It soon became evident, however, that the slow growth rate of the Lusterfjord herring made more accurate measurements desirable, but nothing much has been lost by grouping, when the aim is, as in this Section, simply to gain a general knowledge of the length of the herring. In Table 5, therefore, the length is presented in frequency distributions of 1/2 cm groups. As before, the fish caught within the same calendar month have been grouped together and treated as one sample. The statistics n, $S(x)$, $S(x^2)$, σ^2, σ, and $\pm \frac{2\sigma}{\sqrt{n}}$ are also entered in the Table. The »working mean« is chosen at 20.5 cm.

As will be seen, the monthly means vary quite considerably, from 20.05 cm to 21.05 cm, and there is no definite trend in the variations. A test of homogeneity by Fisher's method (Fisher 1948) shows significant differences between the samples, but this does not necessarily alter the previous conclusion, drawn from the studies of the scale characters and the vertebral numbers, that the samples originate from the same herring tribe. The analysis indicates, however, that the size groups are incompletely mixed in this area, as is also very common in other seas.

Taken as a whole, the length of the mature Lusterfjord herring varies between 17.5 cm and 24 cm during the time interval under consideration. The mean length is 20.86 cm with a sampling variance of the mean = 0.0005 or a standard error = $\pm$ 0.045 cm. The variance of the total length distribution is 0.6816 with a sampling variance of variance = 0.0007 or a standard error = 0.053. To the variance must be added Sheppard's adjustment for grouping $\left(\frac{1}{12}\right)$ and the corrected value of the variance will then be = 0.5983 cm². The standard error of grouping of both the mean and the standard deviations is $= \frac{1}{\sqrt{12n}}$ or in this case = 0.0079 (Fisher loc.cit.). For sufficiently fine grouping this should not exceed $\frac{1}{10}$ of the standard error of random sampling. The grouping in ½ cm therefore is somewhat too coarse to arrive at the correct values, but this cannot be helped unless the samples measured in ½ cm groups are to be left out of the treatment.

One of the most striking features of the Lusterfjord herring when

Table 5. Length frequency distributions of the Lusterfjord herring in the different months of the year Nov. 1949— Nov. 1950. For further explanations see text.

Month	Length in cm													
	.5	18	.5	19	.5	20	.5	21	.5	22	.5	23	.5	24
Nov. -49	—	—	1	7	6	26	15	20	7	5	4	1	—	—
Dec. »	—	1	—	2	4	6	2	4	—	1	—	—	—	—
Jan. -50	—	—	—	—	2	12	15	11	11	1	—	—	1	—
Feb. »	—	—	—	—	—	1	2	4	—	—	—	—	—	—
Mar. »	—	—	—	2	7	31	63	75	57	33	13	4	—	2
Apr. »	—	1	—	8	13	64	113	99	72	46	15	6	1	1
May »	—	—	—	—	—	—	3	2	2	3	1	1	—	—
Jun. »	1	1	—	—	3	15	18	25	7	9	1	—	1	—
Jul. »	—	—	—	3	6	10	22	16	6	3	1	—	—	—
Aug. »	—	—	—	1	6	14	31	17	8	1	1	—	1	1
Sep. »	—	—	—	—	—	4	11	16	5	2	1	—	—	—
Oct. »	—	—	—	1	2	3	13	24	10	4	4	2	1	—
Nov. »	—	—	—	—	3	16	22	20	16	3	1	1	—	—
Total	1	3	1	24	52	202	330	333	201	111	42	15	5	4

compared with the Winter herring, is its smaller size. This will be evident from Fig. 10 where the percentage length frequency distributions are represented in graphical form for the Lusterfjord herring (Nov. -49 — Nov. -50) and the Winter herring (Jan. — March -50). There is no overlapping in the length distributions, the smallest mature specimens of the Winter herring being larger than the »giants« amongst

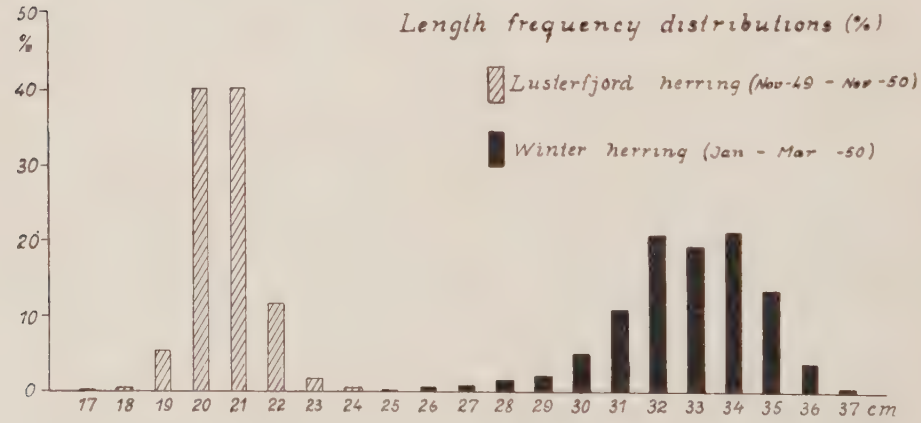

Length frequency distributions (%)
Lusterfjord herring (Nov-49 - Nov-50)
Winter herring (Jan - Mar -50)
50
%
40
30
20
10
0
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 cm

Fig. 10. The length frequency distribution of the Lusterfjord herring Nov. 1949 — Nov. 1950 (hatched columns) compared to that of the Winter herring Jan. — Mar. 1950 (black columns).

20.5 cm + 0

n	$S(x)$	$\bar{x}$	$S(x^2)$	σ^2	σ	$\pm \frac{2\sigma}{\sqrt{n}}$
92	5.5	0.0598	77.75	0.8508	0.9224	0.191
20	— 9.0	— 0.4500	19.50	0.8132	0.9018	0.406
53	13.0	0.2453	30.00	0.5156	0.7181	0.197
7	1.5	0.2143	1.25	0.2548	0.3934	0.297
287	159.5	0.5557	270.75	0.6368	0.7980	0.094
439	182.5	0.4157	372.25	0.6767	0.8226	0.079
12	12.0	1.0000	19.50	0.6818	0.8257	0.477
81	22.0	0.2716	68.50	0.7816	0.8841	0.196
67	5.0	0.0746	36.00	0.5398	0.7347	0.179
81	12.0	0.1481	51.50	0.6215	0.7884	0.175
39	16.0	0.4103	18.50	0.3141	0.5604	0.180
64	39.0	0.6094	67.50	0.8119	0.9011	0.225
82	24.0	0.2927	45.00	0.4688	0.6847	0.151
1324	483.0	0.3648	1078.00	0.6816	0.8256	0.045

the Lusterfjord herring. There can be no doubt that these two are entirely different herring tribes. (See also Plate III).

Weight

The weight of the Lusterfjord herring has been determined in most cases to the nearest gram, and in the first samples to the nearest 5 gram. Unfortunately some data on the weight are lacking during July and a part of August in the absence of the author, when the sampling was carried out by some other members of the staff.

In Table 6 is presented the monthly weight frequency distributions in 5 gm. groups from Nov. -49 to Nov. -50, excepting July for reasons stated above. The total weight distribution appears at the bottom of the Table. Also are entered n, $S(x)$, $\bar{x}$, $S(x^2)$, σ^2, σ, and the standard error of the mean $= \pm \frac{2\sigma}{\sqrt{n}}$. The »working mean« is chosen at 60 gm.

It will be noted that the monthly means vary quite considerably and much in the same manner as the means of the length. The relation between the weight and the length will be considered in the Section: Condition factor. The samples show statistically significant differences between their means. However, this will not necessarily mean that one is not operatingon a single herring stock (See previous Section).

Table 6. Weight frequency distributions of the Lusterfjord herring in the different months of the year Nov. 1949 — Nov. 1950. For further explanations see text.

Month	Weight in gm.													
	40	45	50	55	60	65	70	75	80	85	90	95	100	105
Nov. -49	—	2	7	7	16	20	14	15	2	6	1	2	—	—
Dec. »	1	1	4	5	2	5	1	—	1	—	—	—	—	—
Jan. -50	—	2	8	5	17	12	7	—	1	1	—	—	—	—
Feb. »	—	—	—	—	1	4	2	—	—	—	—	—	—	—
Mar. »	—	1	10	17	41	54	50	50	34	22	7	—	—	—
Apr. »	2	10	31	50	76	86	82	65	18	15	2	1	—	1
May »	—	—	—	1	3	1	1	1	2	3	—	—	—	—
Jun. »	—	1	2	12	19	19	21	6	1	—	—	—	—	—
Aug. »	—	—	—	2	15	14	9	2	—	1	—	—	—	—
Sep. »	—	—	1	1	4	17	13	3	—	—	—	—	—	—
Oct. »	—	1	2	1	10	14	17	10	5	—	2	1	—	1
Nov. »	—	—	1	4	19	21	11	19	7	1	—	—	—	—
Total	3	18	66	105	223	267	228	171	71	49	12	4		2

To gain a general knowledge of the weight of the Lusterfjord herring one may be justified in considering the total weight distribution as a (large) sample from the herring stock, and in fitting this to a normal distribution one obtains the following information:

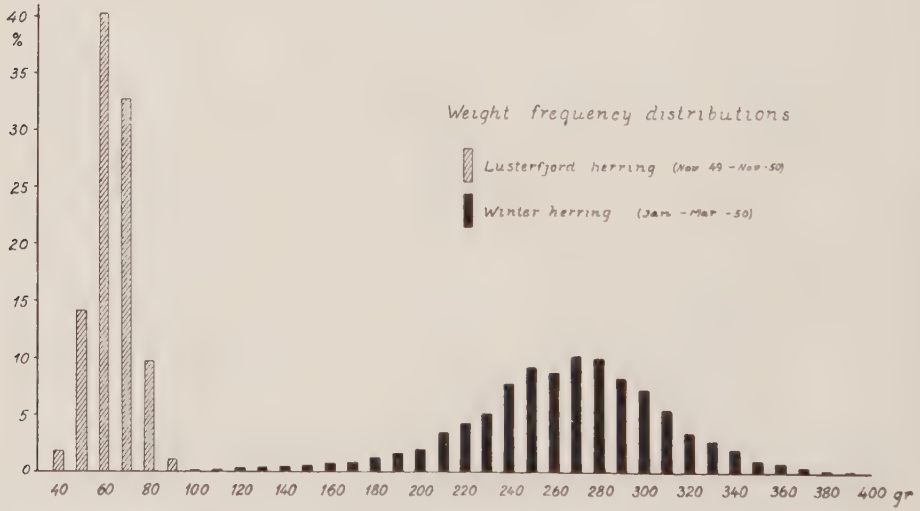


Fig. 11. The weight frequency distribution of the Lusterfjord herring Nov. 1949 — Nov. 1950 (hatched columns) compared to that of the Winter herring Jan. — Mar. 1950 (black columns).

60 gm ± 0

110	115	120	n	$S(x)$	x	$S(x^2)$	σ^2	σ	$\pm \frac{2\sigma}{\sqrt{n}}$
—	—	- -	92	620	6.7391	14 500	113.4259	10.6500	2.22
—	—	- -	20	—45	—2.2500	1 775	88.0921	9.3858	4.20
—	—	-—	53	40	0.7547	3 400	66.0747	8.1287	2.23
—	—	—	7	40	5.7143	300	11.9047	3.4504	2.62
—	—	1	287	2 820	9.8258	56 500	100.6687	10.0330	1.19
—	—	—	439	2 350	5.3531	54 000	94.5667	9.7246	0.93
—	—	- -	12	140	11.6667	3 050	128.7875	11.3490	6.55
—	—	.	81	320	3.9506	5 050	47.3226	6.8792	1.53
—	—	—	43	205	4.7674	2 375	33.2782	5.7687	1.76
—	—	—	39	245	6.2821	2 525	25.9444	5.0935	1.63
—	—	—	64	590	9.2188	11 800	94.2237	9.7069	2.43
—	—	—	83	635	7.6506	9 525	74.0773	8.6068	1.89
—	—	1	1 220	7 960	6.5246	164 800	92.5875	9.6223	0.55

The mean weight is = 66.52 gm. with a sampling variance of the mean = 0.0759 or a standard error = ± 0.55. The variance of the weight distribution is = 92.5875 with a sampling variance of variance = 14.0766 or a standard error = ± 7.5036. To the variance must be added Shephard's correction for grouping = 0.083, and the value of the adjusted variance will then be = 92.5045.

The standard error of grouping $\left(\frac{1}{\sqrt{12n}}\right)$ is here = 0.0082, and it is evident that the grouping in 5 gm. groups is sufficiently fine.

In Fig. 11 is shown the weight distributions of the Lusterfjord herring and the Winter herring, and again the difference between these two herring tribes is clearly demonstrated.

Growth

In those cases where the scales were suitable for the purpose, growth measurements have been carried out and l_1, l_2 ....., l_n calculated using the modified growth formula (Lea 1910, Lea 1938):

$$l = \frac{s}{S} L + 10 \left(1 - \frac{s}{S}\right)$$

Table 7. The lengths (l) of 1, 2, ... 8, years old Lusterfjord herring (mean values with standard error of the mean) for the different year-classes based on scale measurements.

Year-class	n	l_1 cm		l_2 cm		l_3 cm		l_4 cm		l_5 cm		l_6 cm		l_7 cm		l_8 cm	
		Mean	$\pm \frac{2\sigma}{\sqrt{n}}$	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$
1948	17	8.84	0.69	15.41	0.73	—	—	—	—	—	—	—	—	—	—	—	—
1947	20	7.53	0.50	15.06	0.44	17.67	0.27	—	—	—	—	—	—	—	—	—	—
1946	119	8.80	0.13	14.51	0.16	18.22	0.23	20.12	0.16	—	—	—	—	—	—	—	—
1945	492	8.89	0.06	14.69	0.07	18.20	0.08	19.93	0.08	20.75	0.08	—	—	—	—	—	—
1944	103	8.35	0.15	14.00	0.25	17.41	0.22	18.80	0.21	19.73	0.25	20.54	0.21	—	—	—	—
1943	113	8.33	0.17	13.44	0.21	17.00	0.18	18.38	0.17	19.35	0.19	20.16	0.19	20.73	0.16	—	—
1942	30	7.82	0.38	13.38	0.30	16.76	0.37	18.39	0.35	18.95	0.39	20.21	0.33	20.75	0.35	21.24	0.31
1941	3	8.66	1.31	14.80	0.75	16.90	1.11	18.10	0.53	18.90	0.03	19.50	0.03	20.20	0.40	20.70	0.60
1940	1	6.80		14.80		17.70		18.60		19.20		19.70		20.10		20.40	
Total		8.68	0.06	14.41	0.07	17.89	0.08	19.56	0.08	20.32	0.08	20.31	0.13	20.72	0.16	21.17	0.29

where s and S refer to measurements on the scale from the basal line to the winter-ring (s) and to the edge respectively, L is the measured total length, and l the calculated length at the formation of the winter-ring (s). The resulting data are summarized in Table 7, giving the mean values of l_1, l_2, ... l_n and their standard errors for the different year classes.

It will be noted that , as a general rule, the older year classes have an apparently slower growth rate than the younger ones. One has here

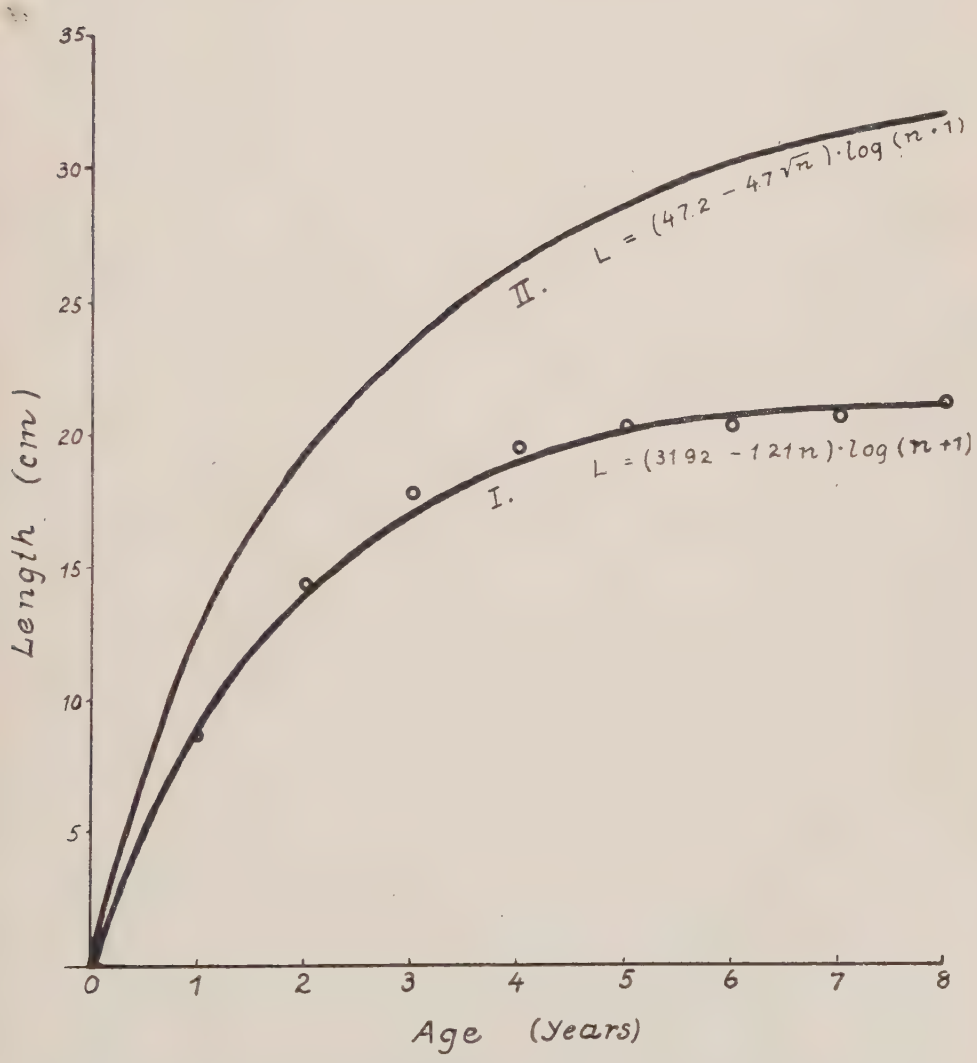


Fig. 12. The growth of the Lusterfjord herring (Curve I) compared to that of the Winter herring (Curve II).

a demonstration of what is commonly known as Rosa Lee's phenomenon: »The phenomenon of apparent change in growth rate« (Rosa Lee 1912). Oscar Sund had earlier noted the same feature for the sprat (Oscar Sund 1911) and further more offered the explanation that this effect is due to the fact that the most fast growing of the younger individuals will attain maturity quicker than the slower growing and thus appear at an earlier age in the shoals of the adult fish. Sund was thus the first to formulate and explain the problem of Rosa Lee. Later Einar Lea proved that the explanation set forth by Oscar Sund, also holds good for the herring (Einar Lea 1913).

In Table 7 is also given the mean values of all the observations on l_1, l_2, ... l_n and their standard errors. It is found that the figures correspond approximately to the formula:

$$\text{(I)} \quad L_n = (31.92 - 1.21\, n) \log (n + 1)$$

where L_n is the length in cm and n the age in years.

In Fig. 12 is given a graphical demonstration of this formula (I). The observed values are entered as small circles. For comparison is also drawn in the approximate growth curve for the Winter herring as found by Oscar Sund (Sund 1944):

$$\text{(II)} \quad L_n = (47.2 - 4.7 \sqrt{n}) \log (n + 1),$$

L_n and n having the same meaning as above (II). Again is demonstrated the difference between the Lusterfjord herring and the Winter herring.

Maturity cycle.

The practice of distinguishing between different stages of maturity in the herring, dates from the nineties of the last century (Heincke 1898), and ever since, Heincke's system has been in use, with only a few alterations (Johansen 1919). When sampling the Winter herring the following description of the stages has been applied:

Stage I	Virgin herring. Gonads very small, 2—3 mm broad. Ovaries wine red, torpedo shaped. Testes whitish or grey brown, knife shaped.
Stage II	Virgin herring. Gonads more of the form as those of adult herring but still small, 5—6 mm broad. Eggs not visible with the naked eye.
Stage III	Gonads more thick and swollen, 1—2 cm broad. Ovaries yellowish, eggs visible with the naked eye. Testes greyish.

Stage IV — Gonads almost as long as the body cavity. Ovaries orange coloured or pale yellow. Eggs large uneven, opaque. Testes whitish.

Stage V — Gonads fill up body cavity. Ovaries yellowish. Eggs round, some hyaline. Testes milk white.

Stage VI — Flowing roe and milt.

Stage VII — Spent herring. Gonads slack. Ovaries blood red, testes greyish red.

Stage VIII — Recovering spent herring. Gonads in firmer condition, about 1 cm broad. Colour dark wine red.

This scale has also been used for the Lusterfjord herring, with modifications as to the measurements given owing to the Lusterfjord herring being so small.

Table 8. Monthly frequency distributions of maturity stages expressed as per cent of examined specimens in the year Nov. 1949 — Nov. 1950.

Month	Maturity stage						n
	VII	VIII	III	IV	V	VI	
Nov. 1949	—	2.2	93.5	4.3	—	—	93
Dec. »	—	10.0	60.0	30.0	—	—	20
Jan. 1950	—	—	48.2	50.9	0.9	—	53
Feb. »	—	—	—	—	100.0	—	7
Mar. »	—	—	—	2.4	45.0	52.6	287
Apr. »	4.3	—	—	0.9	4.5	90.3	439
May »	4.2	45.8	—	—	—	50.0	12
Jun. »	66.7	30.9	—	1.2	0.6	0.6	81
Jul. »	1.6	55.8	42.6	—	—	—	61
Aug. »	—	15.8	84.2	—	—	—	79
Sep. »	—	5.6	94.4	—	—	—	36
Oct. »	—	—	90.6	9.4	—	—	64
Nov. »	—	—	50.0	49.4	0.6	—	82

In Table 8 is shown the percentage frequency distributions of the different maturity stages for each month from November 1949 to November 1950. Although the material is scanty, the figures give a fairly coherent picture of the maturing cycle. Starting with spent herrings it will be seen that Stage VII begins to appear in April, reaches maximum in June and disappears in July. Stage VIII (recovering spents) begins

in May, reaches maximum in July and is found right up to December. Stage III begins in July, reaches maximum in September (November) and vanishes in January. Stage IV starts in October, attains maximum in January and disappears in March (but may be scantily found up to June). Stage V begins in January, reaches maximum in February and disappears in April (occasionally also found later). Stage VI (spawning herring) is found in March, April, and May, mainly in April. A few herrings in Stage VI have also been found in June.

Following the maxima figures through the different months (heavily lined squares) it is found that in June the major part of the herring is in Stage VII, in July Stage VIII is dominating. Through August, September, October, November, and December, most of the herring are in Stage III. In January, Stage IV forms the largest group. In February, Stage V is dominating, and finally, during March, April, and May most of the herring are in spawning condition.

The Table also indicates the approximate duration of the different stages. Stages VII and VIII seem to be of comparatively short duration, about one month each. Stage III lasts longest, about 5 months. Stages IV and V again are of shorter duration, about 2 month's time together. Lastly there is the »spawning period«, stage VI, lasting about 3 months. It must be borne in mind that there are no sharp limits between the different stages, and the building up of the gonads towards the spawning act must be rather regarded as a continuous process, but the analysis of the variation in maturity stages through the year gives but an obscure picture.

It may thus be of interest to look further into the determination of the maturity stages, for as these determinations are based on judgment, doubtful cases will very often occur and one might expect several inaccuracies. Moreover different workers are apt to judge differently. The difficulties are enlarged if the samples are frozen or preserved in other ways, and it would certainly be of advantage if one could find a more empiric method of determining the maturity stages.

It will be noticed, that in the description of the stages, one frequently refers to the bulk or size of the gonads, and this induces the idea of using their weight as a measurement of the stage development (G. P. Farran 1938). In consequence, weighing of the gonads was introduced in the routine sampling, but unfortunately, observations are lacking during the summer months in the author's absence.

The weight of the gonads alone does not give any good expression of the stage of maturity, but must be considered in relation to the fish. Farran introduces a quantity:

$$K_G = \frac{\text{weight of gonad} \times 100}{l^3}$$

where l is the length of the fish, an expression which may appropriately be termed the »condition factor« for the gonads (Farran loc. cit.). In the subsequent treatment of the data for the Lusterfjord herring a somewhat different course is adopted. The changes through the year in the weight of the gonads ($\not p$) are comparatively much greater than the changes in the body weight (P) and the ratio $\frac{\not p}{P}$ may be expected to show sufficiently large variations for distinguishing between different stages of maturity. By multiplying the ratio by 10^2 one gets the weight of the gonads expressed as a percentage of the body weight. This is a handy formula for calculations and its biological meaning is easily understood. The expression will here be termed the »Maturity Factor«[1] and denoted by M_F:

$$M_F = \frac{\not p}{P} \cdot 10^2$$

To calculate M_F from this formula is easy enough, but in order to speed up work, a diagram has been constructed by which M_F is readily found when P and $\not p$ have been determined (Fig. 13). The diagram is very simple and does not need any detailed explanation. The ordinate is M_F and the abcissa the weight P. Curves are drawn in for the functions:

$$M_F = f(P) = \frac{\not p}{P} \cdot 10^2$$

where $\not p$ takes successive values 1, 2, 3, ... These curves are seen to have the form of hyperbolae.

In Table 9 is presented the percentage distributions of M_F for each month in the year 1950, leaving out, of course, the months for which data are lacking. To the right in the Table are entered the mean values of M_F, It will be noticed that mean values are also given for August and September. These averages have been calculated in a different way: When sampling, all the gonads were collected and weighed together, and from the mean weight of the gonads and the mean weight of the fish for these particular months, M_F has been computed.

Starting with October, it is seen that the weight of the gonads

[1] The ratio $\frac{\not p}{P}$ is equal to the ratio $\frac{K_G}{K}$, where K is the condition factor of the herring and K_G the analogous expression for the gonads. Hence the term »maturity factor«.

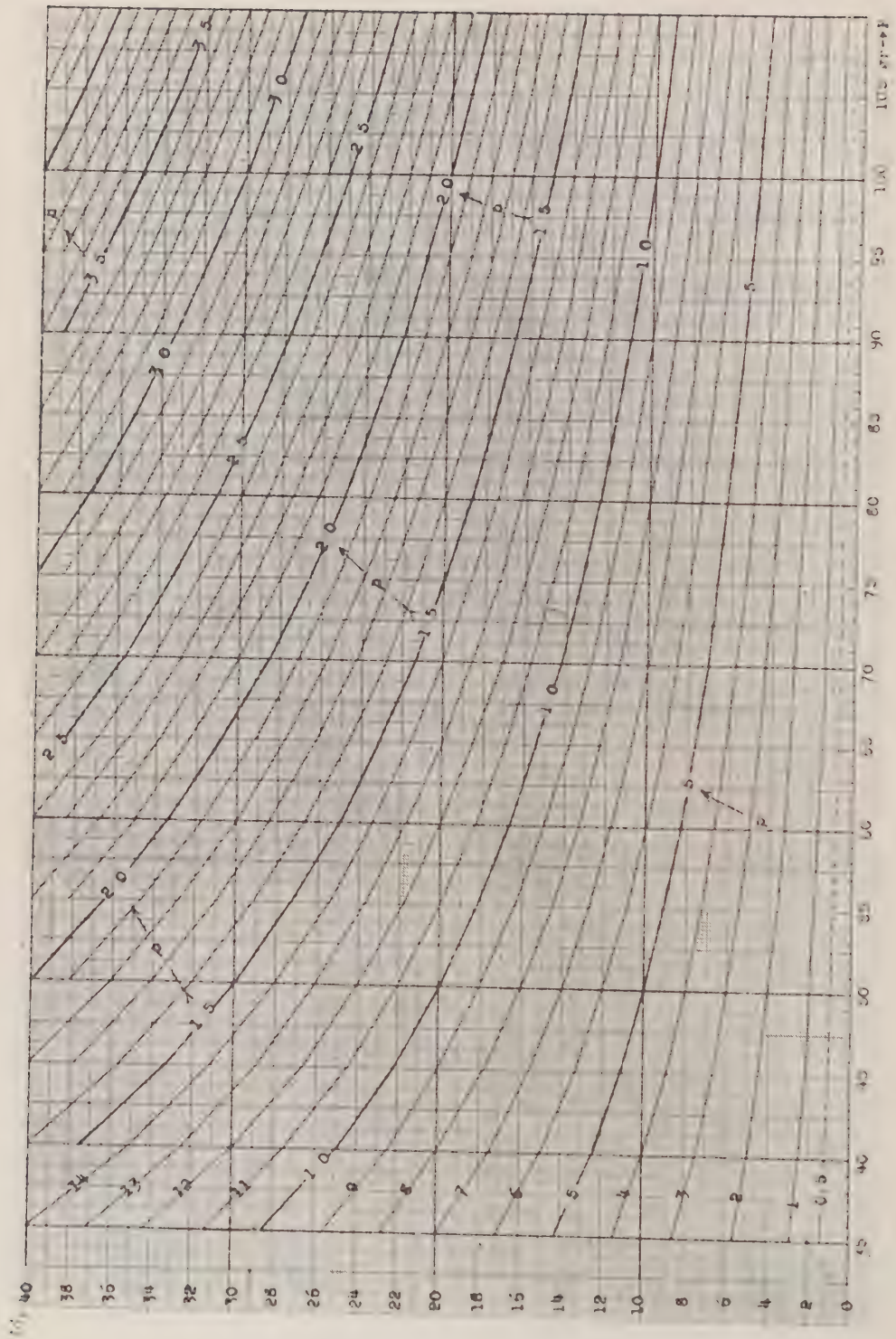
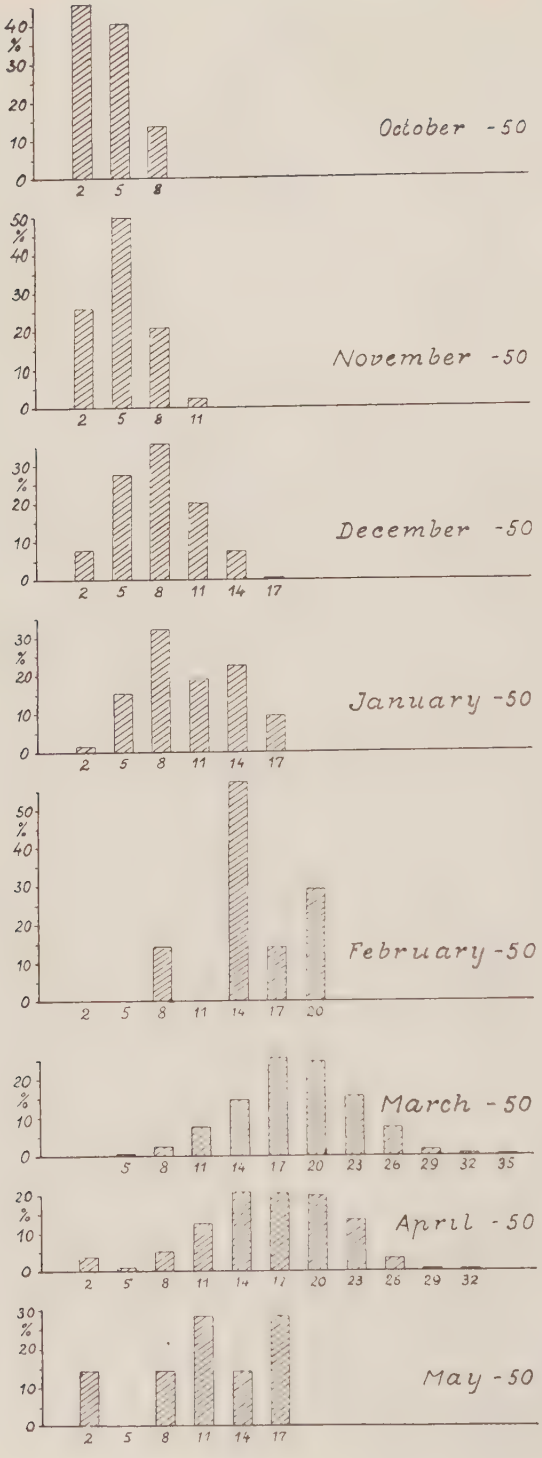


Fig. 13. Diagram for calculation of M_F.

Table 9. Frequency distributions of M_L for the Lusterfjord herring in the months Jan. — May and Oct. — Dec. 1950 expressed as per cent of examined numbers. Mean values of M_F Jan. — May and Aug. — Dec. 1950.

Month	M_F												n	M_F Mean
	2	5	8	11	14	17	20	23	26	29	32	35		
Jan. -50	1.9	15.1	32.1	18.9	22.6	9.4	—	—	—	—	—	—	53	10.2
Feb. »	—	—	14.1	—	57.2	14.1	28.6	—	—	—	—	—	7	14.4
Mar. »	—	0.7	2.4	7.6	14.1	25.6	24.5	15.2	7.6	1.7	0.3	0.3	290	18.5
Apr. »	3.6	1.4	5.0	12.5	20.5	20.3	19.6	13.2	3.2	0.5	0.2	—	439	16.2
May »	14.3	—	14.3	28.5	14.3	28.5	—	—	—	—	—	—	7	11.4
Jun. »	—	—	—	—	—	—	—	—	—	—	—	—	—	-
Jul.. »	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aug. »	—	—	—	—	—	—	—	—	—	—	—	—	—	1.5
Sep. »	—	—	—	—	—	—	—	—	—	—	—	—	—	1.9
Oct. »	45.9	41.0	13.1	—	—	—	—	—	—	—	—	—	61	4.0
Nov. »	26.5	49.4	21.7	2.4	—	—	—	—	—	—	—	—	83	5.0
Dec. »	7.7	27.6	36.5	20.0	7.4	0.8	—	—	—	—	—	—	365	7.8



ranges from about 2 % to about 8 % of the body weight. The 2 % group has the highest frequency. The mean value of M_F is 4.0. In November M_F extends from 2 to 11, with maximum on 5 and average value 5.0. In December the range of M_F is 2 to 17, the highest frequency in the 8 group. The mean value is 7.8. In January (which is one year earlier and not the following month) the range is the same as for December and the 8 groups is still the most frequent, but the 14 and 17 groups are better represented while the 2 and 5 groups are correspondingly reduced. The mean value of M_F has shifted to 10.2. In February M_F extends from 8 to 20, with maximum frequency on 14 and average value 14.4. In March M_F has a very wide range of variation from 5 to 35. This is of course due to the spawning which now is in progress. The mean value of M_F reaches its peak, 18.5. It may be of interest to note that the weight of the gonads can go up to 35 % of the body weight. In other words, about 1/3 of the fish consists of gonads. In April one gets

Fig. 14. Variations in the distributions of M_F prior to and during the spawning.

a similar picture, M_F ranges from 2 to 32. The mean value has gone down to 16.2. In May it is seen that the spawning is nearly completed. M_F extends from 2 to 17. The mean value has further decreased and is now 11.4. In Fig. 14 is given a graphical demonstration of Table 9.

One may be justified in concluding, as a result of this analysis, that it is quite possible to describe the building up of the sexual products in the herring by means of the method just outlined, in a more exact way than was done earlier. Difficulties arise when the herring is in spawning condition, but this stage is well defined anyhow, and errors ought not to occur.

A closer examination of the mean values of M_F through the year reveals a striking picture of the maturing cycle. Starting with the first part of the process (in the summer months) it is noticed that the increase in the bulk of the gonads is slow in the beginning and augments more and more rapidly with time. Thus the increase in M_F from January to March is larger than from June to December. Obviously M_F is a function of the time and this may be expressed:

$$M_F = \varphi(t)$$

where t denotes the time.

The steady augmentation in the increase from one month to the next suggest that $\varphi(t)$ may be expressed as a simple exponential function and it may be postulated:

$$\varphi(t) = p_1 \cdot C_1^t \qquad (p_1,\ C_1 \text{ constants})$$

It is natural to choose the zero time in June when the spawning is completed and the building up process begins. In this system July to March get the numbers 1 to 9. To find the value of C_1 the n^{th} root is extracted of the observed value for the n^{th} month.
In Table 10 is presented the value of C_1 for the different months with an accuracy of one decimal.

Table 10.

Month	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
$\sqrt[t]{\varphi(t)}$	$\sqrt[2]{1.5}$	$\sqrt[3]{1.9}$	$\sqrt[4]{4.0}$	$\sqrt[5]{5.0}$	$\sqrt[6]{7.8}$	$\sqrt[7]{10.2}$	$\sqrt[8]{14.4}$	$\sqrt[9]{18.5}$
C_1	$\frac{1.2}{\sqrt[2]{p_1}}$	$\frac{1.2}{\sqrt[3]{p_1}}$	$\frac{1.4}{\sqrt[4]{p_1}}$	$\frac{1.4}{\sqrt[5]{p_1}}$	$\frac{1.4}{\sqrt[6]{p_1}}$	$\frac{1.4}{\sqrt[7]{p_1}}$	$\frac{1.4}{\sqrt[8]{p_1}}$	$\frac{1.4}{\sqrt[9]{p_1}}$

One will notice that the values of C_1 for August and September fall out in this series. In this connection it may be worth recollecting that the mean values of M_F for these months are calculated by another method than the rest. It is easily realised that the value of p_1 must be a figure very close to 1. One has therefore found it permissible to conclude that the maturing process of the adult herring may be described

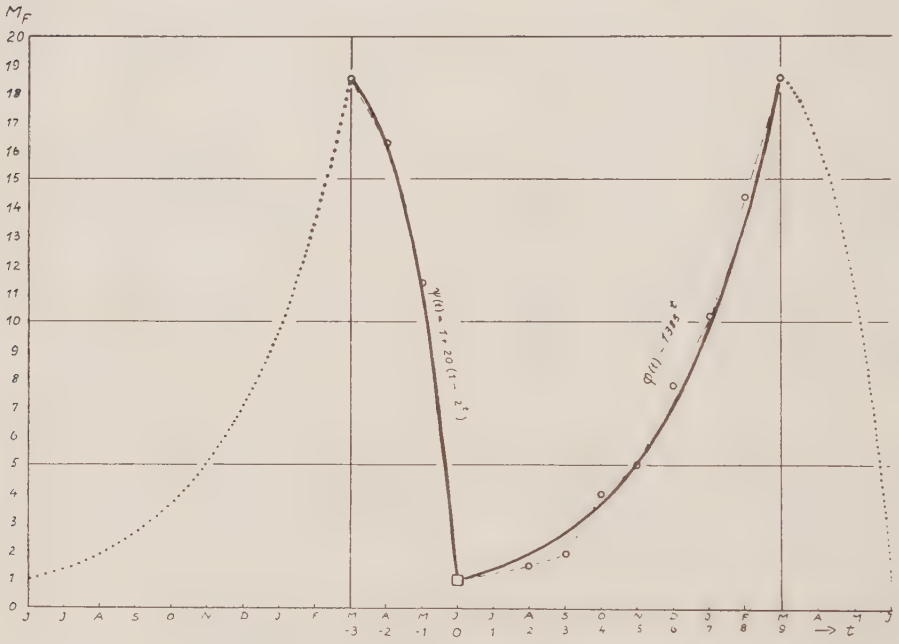


Fig. 15. The variations in the mean values of M_F during maturing and spawning.

by the function $\varphi(t) = C_1^t$, where C_1 is a constant and t the time in months. In Fig. 15 is given a graphical demonstration of the function:

$$\varphi(t) = 1.385^{\,t} \qquad (1.)$$

in the interval June to March (0—9). The observed values for the respective months are represented in this graph as small circles (connected by broken lines).

For the spawning process one finds the opposite trend in the mean values of M_F: M_F decreases with time and the decrease augments from one month to the next. Also here M_F is a function of the time:

$$M_F = \psi(t)$$

of this function $\psi(t)$ is known (the coordinate system being the same as before) that:

$$\begin{aligned} \psi\ (-1) - \psi\ (0) &= 10.4 \sim 10 \\ \psi\ (-2) - \psi\ (-1) &= 4.8 \sim 5 \\ \psi\ (-3) - \psi\ (-2) &= 2.3 \sim 2.5 \end{aligned}$$

or in general

$$\psi(t_n) - \psi(t_{n+1}) = \Theta(t_n) \qquad (n \text{ negative})$$

as evidently also the difference is a function of time. It will be seen that each difference is about half of the next, and this suggest that the general expression of the series may be written:

$$\Theta\ (t_n) = p_2 C_2^{t_n} \qquad (p_2,\ C_2 \text{ constants})$$

Now the value of $\psi(t_n) - \psi(0)$ must equal the value of all the differences up to $\Theta(t_n)$:

$$\psi(t_n) = \sum_{t=-1}^{t-n} \Theta(t_n) + 1$$

or:

$$\psi(t_n) = 1 + p_2 C_2^{-1} + p_2 C_2^{-2} + \ldots + p_2 C_2^{t_n} = 1 + \frac{p_2}{C_2} \cdot \frac{1 - C_2^{t_n}}{1 - \frac{1}{C_2}}$$

or in general:

$$\psi(t) = 1 + p_2 \cdot \frac{1 \quad C_2^t}{C_2 - 1}$$

As already pointed out the value of C_2 is about 2. Using this figure for C_2, one finds the value of $p_2 = 20$. In Fig. 15 is given a graphical demonstration of the function:

$$\psi(t) = 1 + 20\ (1 - 2^t) \qquad (2.)$$

in the interval from $t = -3$ to $t = 0$. The observed values are represented in the graph as small circles (connected by broken lines).

In the preceding account it has been presupposed that the bulk of the gonads in the »building up period« corresponds to the developmental processes in ova and sperms, but to verify this, further studies are necessary. It may therefore be, that M_F is not a precise expression for the maturity as such. For that matter, the same may be said about the earlier defined maturity stages as previously stated. Another circumstance, which may possibly distort the results arrived at, is that the observations from August to December 1950 are combined with the data for January — May 1950 as if they were successive in time. Uncertainty is also introduced by the lack of observations from June and July, and last but not least by the general scarcity of material.

The next step will be to find the connection between the »matu-

rity stages« and the »maturity factor«. In Table 11a the mean values of M_F are entered for each maturity stage from VII to V. As there are few data on the weight of the gonads for stage VII and VIII for the Lusterfjord herring, the values for these two stages are computed from observations on the Norwegian Winter herring during the season 1951.

Table 11 a.

Maturity stage	VII	VIII	III	IV	V
M_F	1.6	1.9	4.5	9.3	18.3

It is seen that M_F varies with the stages and may be regarded as a function of those stages. The mean values of M_F may be supposed to represent the middle of the respective stages which, for the sake of convenience, will be numbered from 1 to 5. The Table takes then the form:

Table 11 b.

Maturity stage	x	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6
			VII		VIII		III		IV		V	
M_F	y		1.6		1.9		4.5		9.3		18.3	

Taking the maturity stage $= x$ as argument and the $M_F = y$ as function of x, one has:

$$y = f(x)$$

The trend in y with increasing x suggest that $f(x)$ is an exponential function:

$$f(x) = K^x$$

To find the value of K, the x^{th} root of $f(x)$ is extracted for the different values of argument:

Table 11 c.

$\sqrt[x]{y}$	$\sqrt[1.5]{1.6}$	$\sqrt[2.5]{1.9}$	$\sqrt[3.5]{4.5}$	$\sqrt[4.5]{9.3}$	$\sqrt[5.5]{18.3}$
K	1.367	1.293	1.536	1.641	1.697

It is seen that K augments with increasing x so that K also is a function of x:

$$K = \varphi(x)$$

Further it will be noticed that the value of K corresponding to Stage VIII, fall out of the series. This puzzling fact has been more closely considered. It turns out that most of the fishes in Stage VIII have been found in the beginning of the season before the spawning had set in (Jan. — Feb.). They consequently do not belong to the spring spawning type, but probably to the South Icelandic summer spawners (Rasmussen 1940). In this direction points also the fact that the herrings in Stage VIII, found in the beginning of the season in the (Norwegian) Winter herring, have a mean vertebral number of 56.93, which corresponds to the South Icelandic summer spawning herring (Einarsson 1951). The difference found in K is therefore not surprising. On the contrary, it was to be expected and must be listed as an interesting observation, as it points towards the circumstance that summer spawners have a maturity cycle somewhat different from the spring spawners, not only in respect of the different spawning time. If the herring in question really belong to the South Icelandic summer spawners and are representative of the stock as to maturity, this would mean that this herring six to seven months after the spawning, are still in Stage VIII, the gonads constituting only 1.9 % of the body weight. The value has, however, to be discarded from the series in question. The other values of K, plotted against x are seen to lie very nearly on a straight line and it may be postulated that:

$$\varphi(x) = ax + b$$

The connection between the maturity stages and the maturing factor is thus expressed by:

$$f(x) = (ax + b)^x$$

The values of a and b are found, by the method of least squares, to be 0.084 and 1.25 respectively. (The correlation coefficient r = 0.92). In Fig. 16 is given a graphical demonstration of the function:

$$f(x) = (0.084\ x + 1.25)^x \qquad (3.)$$

in the interval $x = 1.0$ to $x = 6.0$. The observed values are represented in the graph as small circles.

It must be borne in mind that these formulae (1.), (2.), (3.) only apply to the mean values of M_F. The individual fish may show considerable deviation. This, as far as (3.) is concerned, is largely due to

the uncertainty in the method of determining the maturity stages from a mere general description, the more so as the maturing has now been demonstrated to be a continuous process. One may be justified in con-

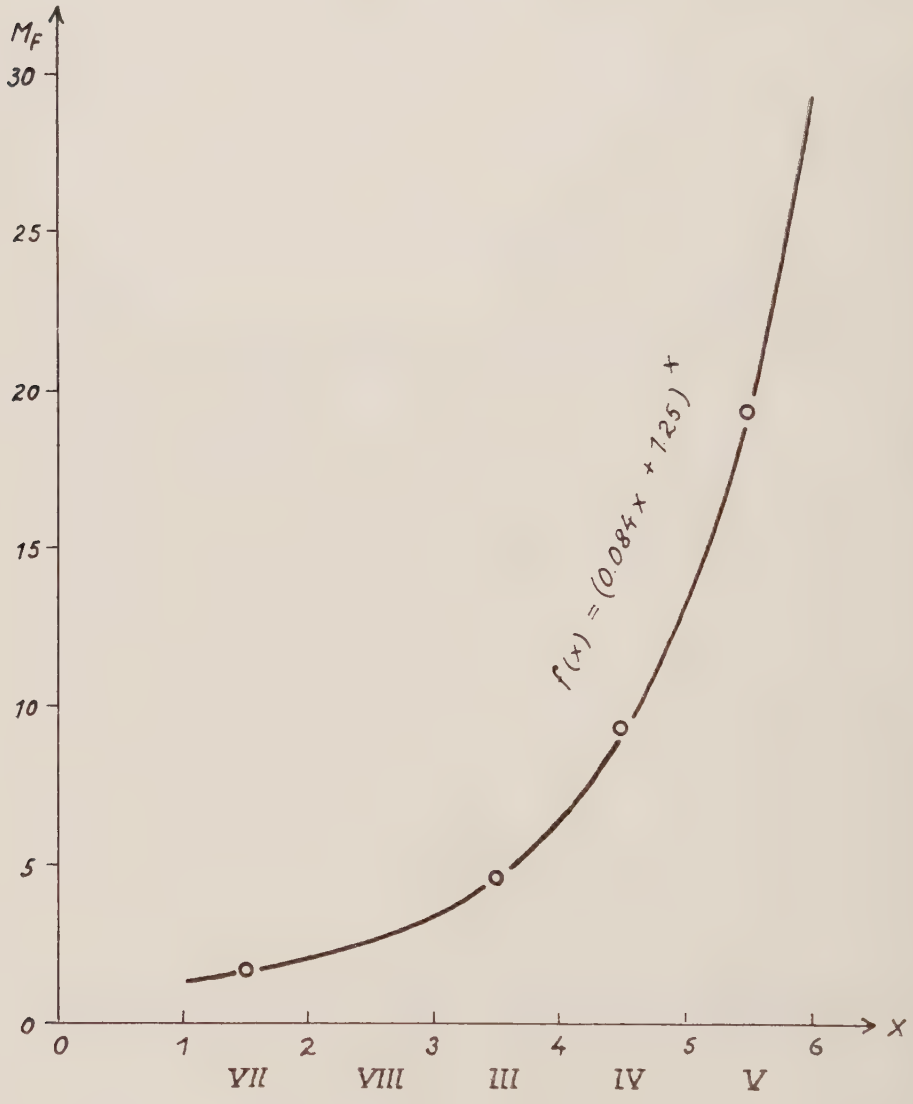


Fig. 16. The connection between the maturity stages and M_F.

cluding that it is to be expected that a more uniform determination of the stage of maturity will be obtained when the weight of the gonads is taken into the picture. For adult herring of a spring spawning type

the following limits of M_F may be used as a guide in checking the estimates of the maturity stages made by Heincke's method, (Table 12):

Table 12.

Maturity factor	← - - - - - 1.9	2.0 - - - - 3.2	3.3 - - - - 5.9	6.0 - - - 13.0	13.1 - - - - →
Maturity stage	VII	VIII	III	IV	V

In connection with the preceding it may be mentioned here that in a paper by Schnakenbeck some references are made to works by Farran and Bowman, Lissner, and Erdmann, where use has been made of the ratio: weight of gonads/body weight, in attempts to determine the maturity stages of herring (Schnakenbeck 1936). Unfortunately, no publications are mentioned ,and the present author regrets not having been able to trace the papers in question. Schnakenbeck (loc. cit.) however, quotes some interesting figures which appear below, giving the limits (of $\frac{p}{P} 10^2$) laid down for the various maturity stages.

Table 13.

Maturity stage	I	II	III	IV	V
Farran and Bowman	<0.5	0.5—3	3—7	7—11	>11
Lissner			<10	10—15	>15
Erdmann	<0.5	0.5—3	3—8	8—13	>13

On comparison of Tables 12 and 13, it will be seen that there are no serious discrepancies between the series except for Lissner's figures. In Schnakenbeck's view, however, the method was regarded impracticable, as the stages showed a wide distribution of the values with great overlappings. But the fact that the findings by the newer method do not correspond exactly with the determination of the stages by the older method, does not furnish any proof of the former's impracticability as long as the precise significance of the maturity stages themselves is incompletely known. The question mark may, as far as present knowledge goes, equally well be put on the older method.

Intestinal fat

One of the characters usually noted when sampling herring, is the amount of intestinal fat. This has also been done for the Lusterfjord herring. The following scale has been used:

0	:	no fat
+	:	traces of fat
++	:	moderate fat
m	:	much fat.

This is, of course, a very rough scale and it is to a large extent a matter of opinion in which group a particular fish is to be placed. The uncertainty is more pronounced when working on an unfamiliar fish such as the Lusterfjord herring was when the work started. This is probably the reason why the observations on intestinal fat in the three first months (Nov.—49 to Jan.—50) show rather queer results. These observations have therefore been discarded when compiling Table 14. The figures appearing in this Table for the months in question are from November and Desember 1950 and January 1951.

In Table 14 are summarized the results of the observations on intestinal fat from February 1950 to January 1951. The frequency in each group is expressed as per cent of the total observations for each month. The means are calculated as the arithmetical means when the groups 0, +, ++, and m are given the values 0, 1, 2, and 3. At the bottom of the Table are entered the values obtained when the means are smoothed after the formula:

$$m = \frac{a + 2b + c}{4}$$

where a, b, and c are successive values in the series.

From Table 14 is seen that herrings with no intestinal fat begin to appear in the samples in November (the 0-group). Through December and January they become more and more frequent. The maximum is reached in February, March, and April when there are no herrings with intestinal fat. As soon as the spawning is finished the herrings begin to feed eagerly and already in July all of them have stored fat reserves in the intestines. The »+ group« shows two maxima and two minima in the year. Herrings with only traces of fat are most frequent in October — December and May — June. The minima fall in February — April prior to and during the spawning and in July — September when most of the herrings have accumulated more fat. Herrings with medium fat in the intestines are found from May to December, mostly in August

— October (the ++ group). In January — April there are no herrings in this category. The last group »*m*« (much fat) increases rapidly from nil in June to maximum frequency in July. From then on it decreases gradually to December.

Table 14. Frequency distributions of intestinal fat (0, 1, 2, 3) for the Lusterfjord herring in the different months of the year Feb. 1950 — Jan. 1951 expressed as per cent of examined specimens.

Month		-50 Nov.	-50 Dec.	-51 Jan.	-50 Feb.	-50 Mar.	-50 Apr.	-50 May	-50 June	-50 July	-50 Aug.	-50 Sep.	-50 Oct.
0	0	1.2	15.4	89.0	100	100	100	57.1	65.0	—	—	—	—
1	+	70.2	51.2	11.0	—	—	—	28.6	21.7	9.4	2.5	7.7	24.6
2	++	26.2	32.1	—	—	—	—	14.3	13.3	23.4	52.5	48.7	67.7
3	m	2.4	1.4	—	—	—	—	—	—	67.0	45.0	43.6	7.7
Number		84	371	100	7	287	439	14	83	64	80	39	65
Mean		1.30	1.19	0.11	0.00	0.00	0.00	0.57	0.48	2.58	2.43	2.36	1.83
Smoothed Mean		1.41	0.95	0.35	0.04	0.00	0.14	0.41	1.03	2.02	2.45	2.25	1.83

In this connection, it is interesting to note that, according to an unpublished report on the plankton in some selected fjords on the west coast of Norway by Kaare Gundersen, not only is the production of zooplankton in the upper layers generally richest in July, but also the quality of the plankton is then at its best. The content of fat and proteins in the plankton reaches a peak in the month of July. For the Lusterfjord there are no analyses of the quality of the plankton, but sampling for this purpose has been in progress for some time. Regarding the volume of plankton per unit of water in the upper layers (50 — 0 m), this is seen to have a slightly pronounced maximum in the beginning of June (Fig. 7), (Kaare Gundersen 1951).

Table 14 shows further that in November-December most of the herrings have only traces of intestinal fat (+). In January—June the majority of the herring are poor in fat and have not even traces of it in the intestines (0). But already in July about 2/3 of the herrings have stored much fat in the intestines (m). In August — October medium fat (++) is the dominating group although closely rivalled by the »m group« for the two first months in this period.

In Fig. 17 is given a graphical representation of Table 14. The change in the content of intestinal fat with time is clearly demonstrated. The Figure (upper part) has been constructed in the following way: The percentage frequencies have been put together in the same consecutive order so as to make up 100 % for each month. The points dividing

the different groups have been connected by straight lines for neighbouring months. The size of the areas thus limited corresponds to the magnitude of the respective groups and it is easy to follow the importance of same through the different times of the year. To make them more conspicuous the areas have been symbolized differently:

Black	:	*m*	= much far
Cross hatched	:	++	= moderate fat
Single	»	+	= traces of fat
Open	»	0	= no fat

The Figure does not need many comments. One can mention the striking fact that the »building up« of the fat reserves goes on much quicker than the »breaking down«. This feature is further illustrated

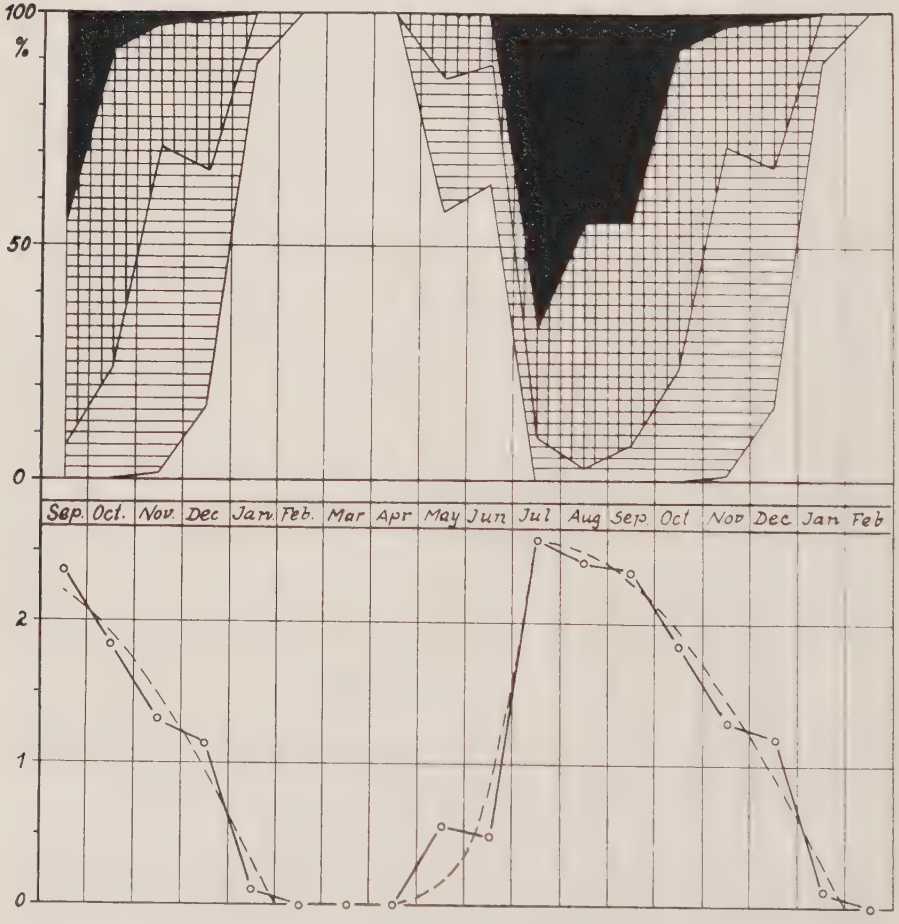


Fig. 17. The yearly variations in intestinal fat.

in the lower part of the figure where the mean values of the intestinal fat content are plotted against the time. It is borne out that while it takes three months to build up the fat from nil to maximum, it takes six months from that time on before the last traces are vanished. This is almost the inverse process found for the building up and the shedding of the sexual products (see previous Section), especially when it is remembered that the last swelling of the gonads is largely due to the absorption of water. It is quite feasible that the processes of the fat storage and the destruction of the accumulated reserves may be described by similar functions as those of the maturing and spawning, only inverted. In Fig. 17 (lower part) is tentatively drawn in the possible courses of such functions (broken lines). The material in hand, however, is not well suited for a further treatment along these lines, based as it is on judgments only.

Condition Factor

When plotting the weight against the length in a sample of fish it is found that the length-weight relation may be approximately expressed by the formula:

$$P = Cl^3$$

where P is the weight, l the length, and C is a proportionality factor. Now the weight of a fish varies (at certain peroids of the year) comparatively more than the length and consequently C will show seasonal variations. This feature has been made use of by various authors to express the condition of the fish by means of C, in herring investigations, for instance, by Paul Bjerkan (Bjerkan 1917), Oscar Sund (Sund 1944)[1], and Aage Jensen (Jensen Aa. 1949). Bjerkan (loc.cit.) computes the average C by using the mean values of P and l. To get figures convenient for tabulating he multiplies C by 10^3 and this expression he calls i (for indicator). Sund (loc. cit.) defines the condition factor, C, as the quantity l^3 has to be multiplied by to equal the weight. From this point of view the formula $P = Cl^3$ is no longer an approximation to the length /weight relation. On the contrary, $C = \frac{P}{l^3}$ is used as an expression for the condition of the fish. Sund (loc. cit.) multiplies C by 10^5 to get figures more handy for further treatment. He terms this new quantity the »Condition Factor« and denotes it by K:

$$K = C \cdot 10^5 = \frac{P}{l^3} \cdot 10^5$$

[1] Oscar Sund, also used the length/weight relation in sprat investigations (Sund 1911).

Which peculiar attributes of the herring K actually expresses, is not evident from the formula, but this point may be elucidated through the following reasoning:

The weight (P) is equal to the volume of the fish (V) multiplied by the specific weight (s).

$$P = V \cdot s$$

The volume may be expressed as the product of the mean height (h), the mean breadth (b), and the length (l)

$$V = b \cdot h \cdot l$$

Then one has:

$$(K \cdot l^2)l = (b \cdot h \cdot s)l$$

or

$$K = \frac{b \cdot h}{l^2} s = \frac{b}{l} \cdot \frac{h}{l} \cdot s$$

This means that K is the product of the ratios: mean breadth/length and mean height/length multiplied by the specific weight. In Fig. 18 is attempted an illustration of those properties of the fish that are involved in K as defined above.

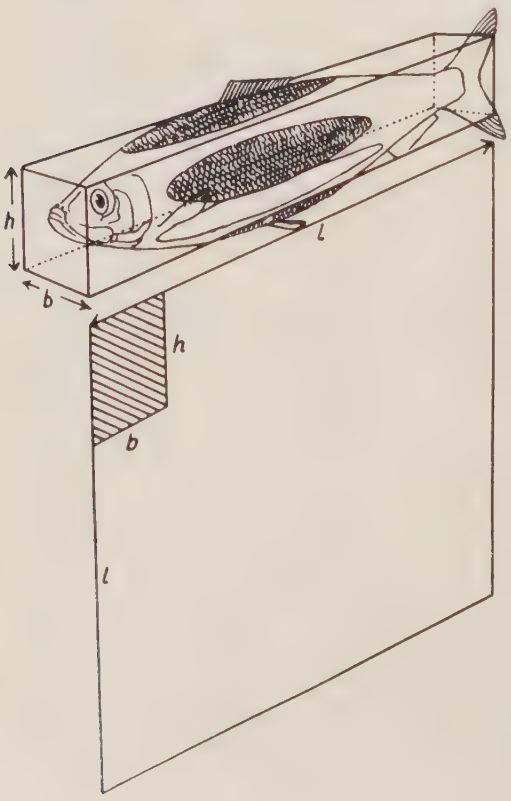


Fig. 18. Diagrammatic representation of the condition factor.

In Table 15 the calculated values of K are summarized giving the frequency distributions in percentages for each month from November 1949 to November 1950 leaving out July as there are no observations on weights in this month. To the right in the Table is entered the number of specimens, the mean values of K, and their standard errors. The first part of this Table presents a rather puzzling picture of the variations in the condition factor. There seems to be a pro-

Table 15. Monthly frequency distributions of the condition factor in the year Nov. 1949 — Nov. 1950 expressed as per cent of examined numbers. Monthly mean values of K and their standard errors.

Month	K											n	Mean	$\pm \frac{2\sigma}{\sqrt{n}}$
	500	550	600	650	700	750	800	850	900	950	1000			
Nov. -49	—	—	—	5.5	15.4	37.4	33.0	5.5	2.2	1.1	—	91	764	11
Dec. »	—	—	—	25.0	35.0	35.0	—	—	5.0	—	—	20	715	24
Jan. -50	—	3.6	12.7	30.9	32.7	16.4	3.6	—	—	—	—	55	675	15
Feb. »	—	—	—	14.2	85.7	—	—	—	—	—	—	7	693	15
Mar. »	—	1.0	2.1	10.7	25.6	30.4	22.1	5.9	0.7	1.0	0.3	289	742	8
Apr. »	0.2	0.7	8.9	18.5	31.1	26.5	10.7	2.5	0.9	—	—	438	710	6
May »	—	—	16.7	8.3	50.0	16.7	—	8.3	—	—	—	12	700	39
Jun. »	—	2.4	4.7	23.5	36.5	22.4	5.9	4.7	—	—	—	85	704	14
Aug. »	—	—	—	17.4	47.8	13.0	21.7	—	—	—	—	23	720	22
Sep. »	—	—	—	8.9	35.7	33.9	14.3	7.1	—	—	—	56	738	14
Oct. »	—	—	1.5	6.2	30.8	38.5	18.5	4.6	—	—	—	65	740	13
Nov. »	—	2.4	3.6	7.2	20.5	34.9	24.1	4.8	2.4	—	—	83	743	15

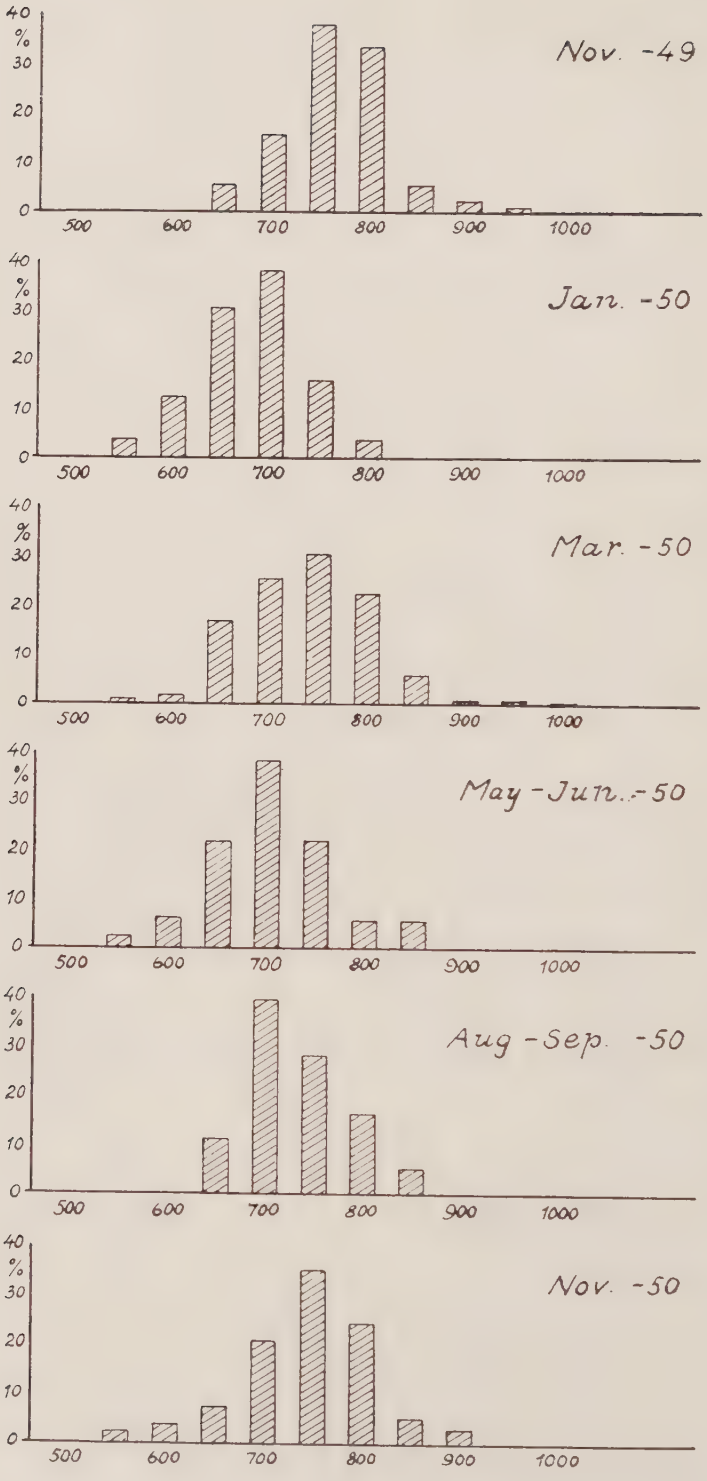


Fig. 19. Variations in the frequency distribution of K at different times of the year.

nounced decrease in the value of K from November to January and then again an almost equally distinct rise to March. This phenomenon, that K shows a minimum before the spawning, may or may not be a general feature. It is not altogether unlikely because, as mentioned before, the last swelling of the gonads before spawning is largely due to absorption of water. During the spawning K naturally decreases and reaches a new minimum in May. From there, the condition factor rises gradually to November, which also seems natural.

In Fig. 19 is given an illustration of the changes in the frequency distributions of K during the year. The variations mentioned are easily followed.

It is to be expected that there is a connection between the fat content of the herring, the maturity factor, and the condition factor, Fig. 20 presents a graph of the three characters giving the variations in the mean values through the year. The scales have been chosen so that the variations show approximately the same magnitude in the graph. For Curve I (the condition factor) the figures appearing in Table 15 are used. For Curve II (intestinal fat) are used the smoothed mean values in Table 14. For the maturity factor (Curve III) the formulae presented on pages 44 and 45 have been applied.

It will be seen that while there is a negative correlation between the amount of intestinal fat and the amount of sexual products, the

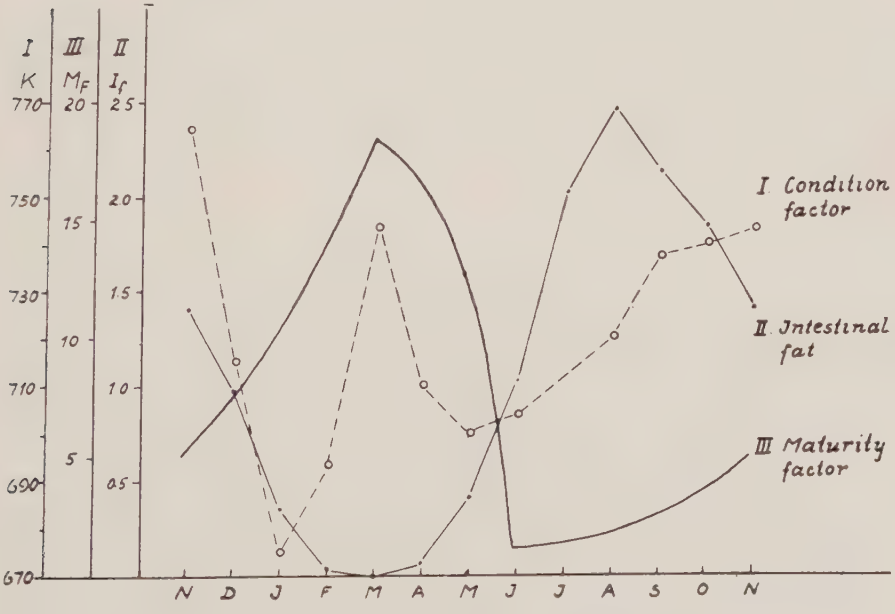


Fig. 20. The interrelation between maturity factor, intestinal fat, and condition factor.

curve for the condition factor runs mostly a course between the two others. That the condition factor is high when spawning starts is mostly due to the bulk of the ripe gonads. In the beginning of the summer, when the herring is newly spent, there is a small amount of fat and the gonads are empty. Consequently the condition factor is low. The amount of rises rapidly during the summer, while the development of the sexual organs is slow. The rise in the condition factor is here due to accumulation of fat. In the autumn the condition factor continues to increase, in spite of the intestinal fat content going down. The rise is here probably due to the rapidly growing gonads. It must be borne in mind, however, that much of the fat in the herring is stored in the muscles. The intestinal fat is only an indicator (and maybe not even a good one) of the quality of the herring. The course of the curve for the condition factor from autumn to spawning will not be discussed here as further observations are desirable before any statement be made.

Sund (loc. cit.) maintains the view that the quality of the herring can be judged by means of K. It is easy to realise that this idea is only partly true. At some time of the year one may have bulky herring full of fat and with high value of K. At some other time one may have equally bulky herring with a similar value of K, but with well developed sexual organs and a much lower fat content. Within shorter periods of the year, however, the condition factor may have a limited value in judging the quality.

When comparing the mean values of K for the Lusterfjord herring and the Winter herring (Sund loc. cit. Table 1) at corresponding times, it will be noticed that the condition factor is higher for the latter: The herring of the two tribes have, in addition to all the other differences, also different body proportions.

SUMMARY

The idea of starting the series of investigations, the results of which so far are presented in the preceding, is founded on the assumption that a local herring race in certain respects represents a miniature model of the larger herring stocks which live in the oceans. By keeping such a local herring race under continuous observation it is hoped that certain disputed problems in the herring's biology may be solved with a reasonable amount of effort. For the purpose a newly discovered herring tribe in the Lusterfjord was selected. For this herring the name »Lusterfjord Herring« is proposed.

The main task of these first investigations was to establish the Lusterfjord herring as a tribe of its own. In this respect the results are satisfactory, though there is, to a small extent, mixing with foreign elements which can be referred to two types. One of these is identical with the Norwegian Winter herring. The usual whereabouts of the other type is not known.

The main characteristics of the Lusterfjord herring are its short life cycle, slow growth rate, low vertebral number, and small size of the fully grown animal:

The age of the sexually mature specimens (in 1950) ranges from 2 to 10 years, the 1945 year-class is dominating.

The mean vertebral number is 56.25 ($\pm$ 0.05) The year-classes show no significant differences between their mean vertebral numbers.

The mean length and the mean weight are 20.86 cm ($\pm$ 0.05) and 66.52 gr ($\pm$ 0.55) respectively.

The herring grow very slowly after 4—5 years, at which age it appears in maximum strength in the shoals of adult fish. Thus the mean length of 4 years old herring is 19.56 cm ($\pm$ 0.08) while the same value for the 8 years old fish is 21.17 cm ($\pm$ 0.29). The growth may be approximately described by the formula:

$$L_n = (31.92 - 1.21\ n) \log\ (n + 1)$$

The maturity cycle is established for the Lusterfjord herring using the description of the stages applied to the Winter herring. The approximate durations of the different stages may be set to (mean values):

Maturity stage	VII	VIII	III	IV	V	VI
Time in months	1	1	5	1	1	3

The maturity cycle has been more closely considered. The weight of the gonads expressed as per cent of the body weight (M_F) is found to vary, in the maturing period, approximately after the formula (mean values):

$$M_F = 1.385^{\,t}$$

where t is the time in months. For the spawning the formula:

$$M_F = 1 + 20(1 - 2^t)$$

applies, the co-ordinate system being the same as for the formula above with origo in the month of the year (June) when the spawning is finished

and the building up period begins. The spawning takes place in March — May, mainly in April. The connection between the maturity stages and M_F is expressed by the formula:

$$M_F = (0.084x + 1.25)^x$$

where x is the maturity stages VII, VIII, III, IV, and V numbered from 1 to 5. In accordance with this formula the following limits of M_F for the different stages are proposed:

	2.0	3.3	6.0	13.1
VII ↓	VIII	III	IV	V
1.9	3.2	5.9	13.0	↓

These values agree reasonable well with corresponding figures found by Farran & Bowman and Erdmann (according to Schnakenbeck).

The intestinal fat cycle has been established. The figures are based on judgments only and may merely be taken as presenting a general picture. Broadly speaking the herring is fat in the summer time and lean in the winter as was well enough known beforehand. The building up of the intestinal fat reserves goes much quicker than the breaking down of the accumulated stores. Maximum of intestinal fat is found in July, minimum in February—April. The amount of intestinal fat and the M_F appear to be negatively correlated.

The condition factor has been considered. This quantity appears to be mainly influenced by the variations in the fat content in the summer months and by the variations in the maturity factor at other times of the year. Shortly before spawning the figures show a peculiar minimum in K which is not accounted for.

The Lusterfjord has been examined as to bottom topography and the results have been charted (Plate I). It appears that the herring has (physically) completely free access to the open ocean. The herring spawn mainly at Ottum in the innermost part of the fjord, the bottom there being rocky with large stones, but herring eggs have been found also on clay bottom.

The hydrography of the Lusterfjord has been investigated as to temperature, salinity, and oxygen content. The herring spawn mainly between 5 and 15 m depth. This water-layer holds at the spawning time 5—7° C, 31—33 ‰ S, and approximately 8 cm²/liter O_2.

The fauna of the Lusterfjord has also considered, especially the plankton. A survey of the occurrence of the different species in the different months (1950) has been prepared. The maximum plankton production (volume per haul) is found in early June. Also a fauna list

for the more common species of the benthos and a similar list for the nekton have been compiled.

It remains only to be said in conclusion that the Lusterfjord herring and its environment is well suited for the purpose of studying the biology of herring in relation to external factors in a local population, and it is strongly recommended that the investigations be continued.

LITERATURE

Bjerkan, Paul 1917: »Age, Maturity and Quality of North Sea Herrings during the Years 1910—13«. Rep. on Norw. Fishery and Mar. Invest. Vol. III. No. 1. Bergen 1917.

Broch, Hjalmar 1908: »Norwegische Heringsuntersuchungen während der Jahre 1904—1906. Unsere Heringsstamme und ihre Wanderungen«. Bergens Museums Årbog 1908 No. 1. Bergen 1908.

Einarsson, Hermann 1951: »Racial Analysis of Icelandic Herrings by Means of Otoliths«. Rapp. et Proc.-Verb. Vol. CXXVIII. Copenhagen 1951.

Farran, G. P. 1938: »On the Size and Number of the Ova of the Irish Herrings«. Journal du Conseil, Vol. XIII, No. 1.

Fisher, R. A. 1948: »Statistical Methods for Research Workers«. Tenth Edition. Oliver and Boyd. Edinburgh 1948.

Fisher, R. A. and Yates, Frank 1949: «Statistical Tables for biological, agricultural and medical Research«. Third Edition. Hafner publishing Co. Inc. New York 1949.

Gundersen, Kaare 1950: »Foreløbig meddelelse til Hermetikkindustriens laboratorium, Stavanger, over planktonundersøkelser i brislingfjorder på Vestlandet«. (Manuscript not yet published). Bergen.

Gundersen, Kaare 1951: »Foreløbig meddelelse over åteundersøkelser i brislingfjorder på Vestlandet 1950«. (Manuscript not yet published). Bergen.

Heincke, Fr. 1898: »Naturgeschichte des Herings I. Die Lokalformen und die Wanderungen des Herings in den Europäischen Meeren«. Abhandlungen d. deutschen Seefischerei Vereins. Bd. II. Berlin 1898.

Hjort, Johan 1914: »Vekslingerne i de store fiskerier«. H. Aschehoug & Co. (W. Nygaard). Kristiania 1914.

Jensen, O. S. 1881: »Praktisk-Videnskabelige Undersøgelser over Vaarsildfisket i 1880». Indberetning til Departementet for det Indre. Christiania 1881.

Jensen, Aage 1949: »Ændringer i sildens kvalitet i årets løb og fra år til år.« Beretning til Fiskeriministeriet fra Den danske biologiske station. Nr. 51. København 1949.

Johansen, A. C. 1919: »On the large Spring-Spawning Sea Herring (Clupea harengus) in the North-West European Waters«. Medd. fra Komm. for Havundersøgelser. Serie Fiskeri. Dd. V. Nr. 8. København 1919.

Lea, Einar 1910: »On the Methods used in Herring Investigations«. Publications de Circonstance. No. 53. Copenhagen 1910.

Lea, Einar 1913: »Further studies concerning the Methods of calculating the Growth of Herrings«. Publications de Circonstance No. 66. Copenhagen 1913.

Lea, Einar 1938: »A Modification of the Formula for Calculation of the Growth of Herring«. Rapp. et Proc.—Verb. Vol. CVIII. Copenhagen 1938.

Lee, Rosa M. 1912: »An Investigation into the Methods of Growth Determination in Fishes«. Publications de Circonstance. No. 63. Copenhagen 1913.

Rasmussen, Thorolv 1940: »Islandssild i Norske kystfarvann«. Rep. on Norw. Fishery and Mar. Invest. Vol. VI. No. 4. Bergen 1940.

Rasmussen, Thorolv 1941: »Borgepollsilda«. Rep. on Norw. Fishery and Mar. Invest. Vol. VII. No. 1.
Bergen 1941.

Sars, G. O. 1891: Praktisk-Videnskabelige Undersøgelser af Trondhjemsfjorden«. Indberetning til Departementet for det Indre. Christiania 1891.

Schnakenbeck, W. 1936: »The present State of Knowledge concerning the Origin and Distribution of Herring Populations in Western European Waters«. Rapp. et Proc.-Verb. Vol. C. Copenhagen 1936.

Sund, Oscar 1911: »Undersøkelser over brislingen i norske farvann vesentlig paa grundlag av »Michael Sars's« togt 1908«.
Aarsberetning vedkommende Norges Fiskerier 1910. Bergen 1910.

Sund, Oscar 1944: »Fisken og havet. Sildeundersøkelser i 1941«. Rep. on Norw. Fishery and Mar. Invest. Vol. VII. No. 6. Bergen 1944.

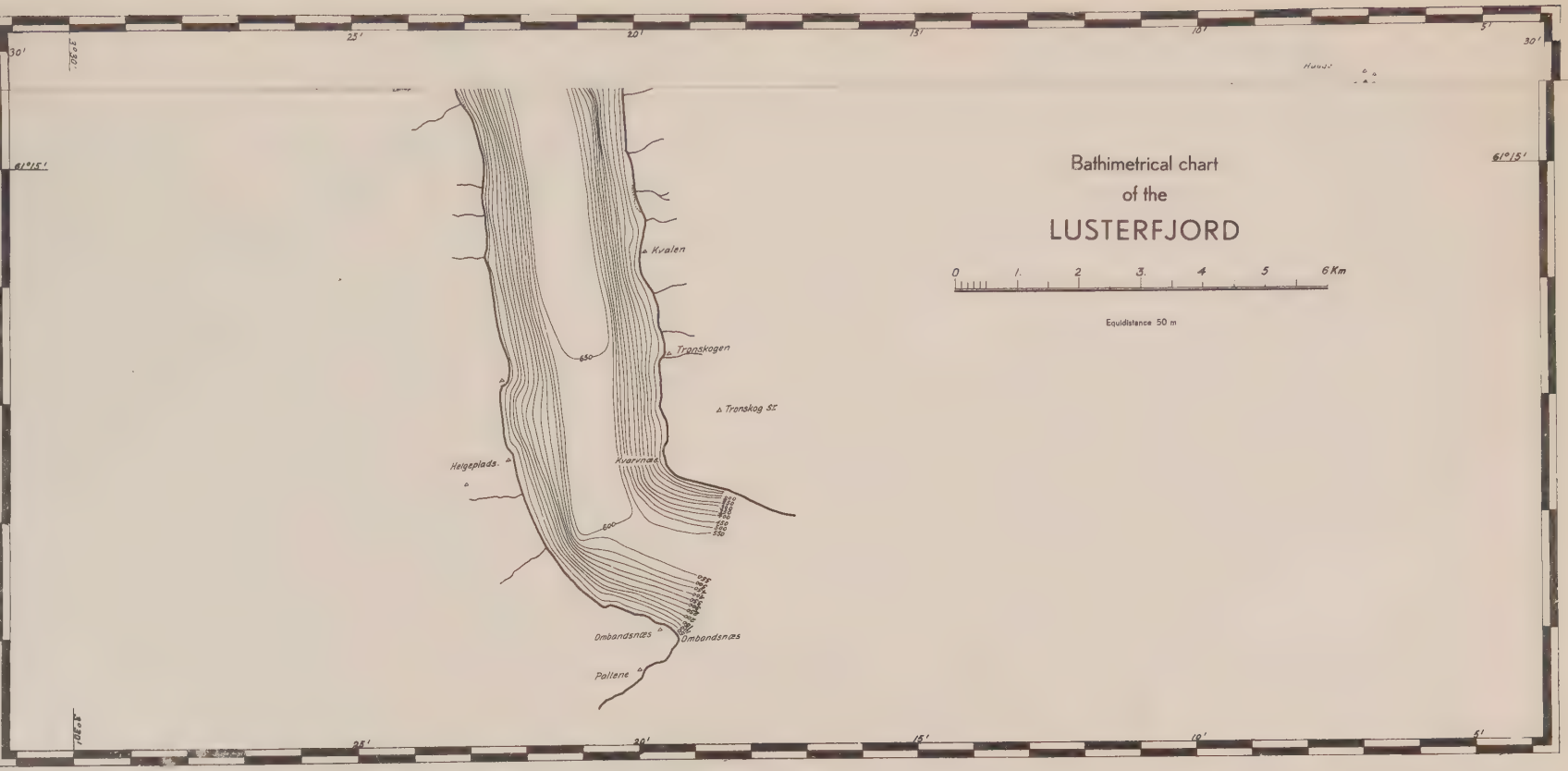


Plate I. Bottom topography of the Lusterfjord.

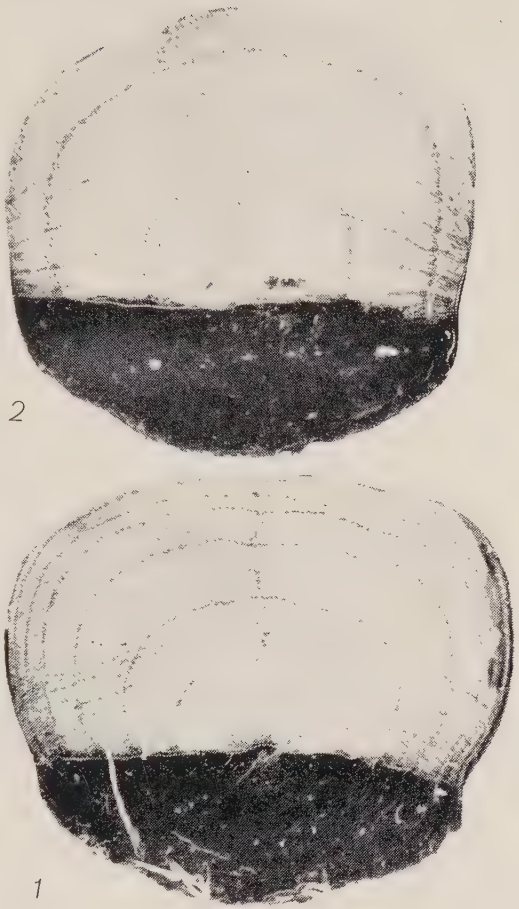
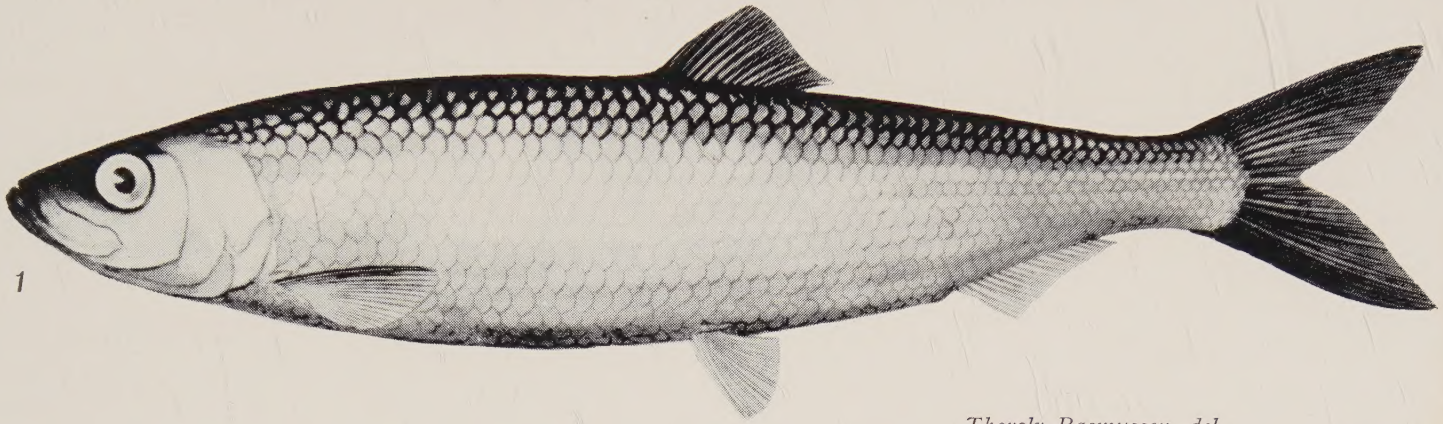


Plate II. 1. Scale from 7 years old Lusterfjord herring. x 9.

2. Scale from 2 years old herring of an unidentified type (»Strange« herring B). x 9.

3. Scale from 7 years old Winter herring (»Strange« herring A). x 9.



1

Thorolv Rasmussen, del.

2

Plate III. The relative sizes of average Winter herring (1) and Lusterfjord herring (2).